Attachment B: Noise Analysis of Taxi Queuing Alternatives for Taxiway November at Logan International Airport

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Prepared for:

Federal Aviation Administration
600 Control Tower, 19th Floor
Logan International Airport
East Boston, Massachusetts 02128

Prepared by:

Christopher Menge
Bradley Nicholas
Robert Miller

HARRIS MILLER MILLER & HANSON INC.
77 South Bedford Street
Burlington, MA 01803

EXECUTIVE SUMMARY

This document represents Attachment B to the main report "Logan International Airport, Additional Taxiway Evaluation Report."[1] This Attachment presents the noise analysis of the use of Taxiway November conducted by the Federal Aviation Administration (FAA) and Harris Miller Miller & Hanson Inc. (HMMH).

HMMH was engaged by FAA to evaluate the noise effects of alternative scenarios pertaining to the queuing of aircraft on Taxiway November and on the proposed new Centerfield Taxiway whose impacts were assessed in the *Environmental Impact Statement for Logan Airside Improvements Planning Project*. The Phase 1 work reported here is designed to address requirements of the *Record of Decision* on the EIS, and addresses the two alternative scenarios of aircraft queuing on Taxiway November:

1. Free Flow – Unconstrained queuing of aircraft operations on Taxiway November
2. Limit All Jets – A maximum of five turbojet aircraft queued north of the intersection with Runway 15L *at all times*.

Noise modeling and measurements were conducted to evaluate the potential difference in noise exposure in the surrounding community between the two taxi queuing alternatives. Detailed noise evaluations were performed at the four permanent noise monitoring stations closest to Taxiway November, including NMS 7 at Loring Rd. near Court Rd. in Winthrop, and NMS 9 at Bayswater St. and Annavoy St., NMS 10 at Bayswater St. near Shawsheen Rd., and NMS 12 at the East Boston Yacht Club, all in East Boston.

The modeling resulted in Day-Night Sound Level (DNL) values for taxi operations during a worst-case busy day, during which Runways 22L and 22R are in constant use for departures. Flight operations (arrivals, departures, take-off roll, thrust reverse, overflights) were ignored in order to focus only on taxiway noise and emphasize the difference between the queuing alternatives. The model results compared favorably with measurements of "non-event" noise at the monitors during that time.

The results showed extremely small differences between the two taxi queuing alternatives. The maximum improvement in DNL computed at any monitor site was 0.1 decibels, under the worst-case condition of Runways 22L and 22R in constant use for departures. The average reduction in taxiway noise between the Free Flow Alternative and the Limit All Jets Alternative is 0.05 decibels. This difference is substantially less than FAA's 1.5-decibel threshold of significance, so no significant reduction in noise impact is expected from implementing an alternative that limits aircraft queuing.

[1] "Logan International Airport, Additional Taxiway Evaluation Report per FAA August 2, 2002 Record of Decision," Harris Miller Miller & Hanson Inc. Report 300280.001, May 2006.

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1 INTRODUCTION

This document represents Attachment B to the main report "Logan International Airport, Additional Taxiway Evaluation Report."[2] This Attachment presents the noise analysis of the use of Taxiway November conducted by the Federal Aviation Administration (FAA) and Harris Miller Miller & Hanson Inc. (HMMH).

1.1 Background and Study Purpose

HMMH was engaged by the FAA to evaluate the noise effects of alternative scenarios pertaining to the queuing of aircraft on Taxiway November and on the proposed new Centerfield Taxiway whose impacts were assessed in the *Environmental Impact Statement for Logan Airside Improvements Planning Project* ("EIS"). The Phase 1 work reported here is designed to address requirements of the *Record of Decision* on the EIS in which the FAA deferred a decision on the new taxiway pending an additional analysis of taxiway operations on the northern portion of the airfield "to assess potential beneficial operational procedures that would preserve or improve the operational and environmental benefits of the Centerfield Taxiway."[3]

As described in the main report, candidate actions to address community concerns were identified by community members and the FAA for review and consideration. Candidate Action 2 would revise the existing Noise Abatement Order ("good neighbor" policy) to limit the number of queued aircraft on Taxiway November at all times, rather than "when possible," as the current order states. Such a revised order would state that no more than five jet aircraft would be permitted to queue north of Runway 15L.

Candidate Action 2 was determined to warrant further operational and environmental analysis. The operational details of this Action are reported in Attachment A to the main report. The noise analysis associated with Candidate Action 2 is presented in detail below in this Attachment.

1.2 Study Overview

1.2.1 Alternative Operational Scenarios

The approach taken to the evaluation was to "bracket" the potential environmental effects of changes to the Noise Abatement Order by examining two extremes of its use. One extreme would have the Order not implemented at all, and the other would have the Order implemented and required at all times. Therefore, two alternative scenarios of aircraft queuing on Taxiway November were developed:

1. Free Flow – Unconstrained queuing of aircraft operations on Taxiway November

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[2] "Logan International Airport, Additional Taxiway Evaluation Report per FAA August 2, 2002 Record of Decision," Harris Miller Miller & Hanson Inc. Report 300280.001, May 2006.

[3] Lewis, Paula, Department of Transportation, Federal Aviation Administration New England Region, "Record of Decision, Airside Improvements Planning Project, Logan International Airport, Boston, Massachusetts," Section VIII (3); 2 August 2002.

2. Limit All Jets – A maximum of five turbojet aircraft queued north of the intersection with Runway 15L *at all times*.

In the summer of 2003 during a 24-hour period when Runways 22R and 22L were in continuous use for departures, FAA staff in the tower kept a detailed log of the status of the queue on Taxiway November. This log was used to develop a model of the taxi and queue/hold times for each aircraft during that day. The model was then extended to compute taxi/queue times under the Limit All Jets restricted flow condition. Finally, the times were scaled up to represent worst-case busy-day aircraft volumes. A summary of the taxi/queue time model and the results for the two alternatives are given in Section 3.3.3 below. More complete details on the model development and results are given in the Taxiway November Operations report, which is included as Attachment A to the main report.[4]

1.2.2 Receiver Positions for Noise Evaluation

The noise evaluation was performed at the four permanent noise monitoring stations closest to Taxiway November and the proposed Centerfield Taxiway. They are:

- NMS 7 – Loring Rd. near Court Rd., Winthrop
- NMS 9 – Bayswater St. at Annavoy St., East Boston
- NMS 10 – Bayswater St. near Shawsheen Rd., East Boston
- NMS 12 – East Boston Yacht Club, East Boston

1.2.3 Measurements and Modeling

The evaluation of the noise effects of the two queuing scenarios was performed through modeling of the aircraft noise emissions during taxi and hold operations at the locations and times derived from the FAA logs. The modeling incorporated sound propagation from Taxiway November to the four NMS sites, and summed the contributions from all taxiing/holding aircraft for a 24-hour period to compute DNL values at each NMS site. Modeling details are presented in Section 3.

The study also evaluated noise measurements conducted at the monitoring stations for purposes of comparison with the modeling results and to assess the relative contributions to DNL of taxi operations and other activities, such as flight operations. Measurement comparisons are presented in Section 4 of this report.

1.2.4 Results

Study results and conclusions are presented in Section 5 of this report. Appendices are provided with details on the fundamentals of noise metrics, aircraft noise emissions used in the modeling, and contributions to the computed overall noise levels by taxi location.

[4] "Attachment A: Operational Analysis of Taxi Queuing Alternatives for Taxiway November at Logan International Airport," Harris Miller Miller & Hanson Inc. Report 300280.002, May 2006.

2 NOISE CRITERIA

This section details FAA's noise regulations and criteria that are applicable to the noise evaluation of Taxiway November.

2.1 Regulatory Context

A list of Federal statutes and FAA regulations related to the consideration of noise impacts follows:

- 49 U.S.C. 47501-47507; The Aviation Safety and Noise Abatement Act of 1979, as amended
- 49 U.S.C. 40101 et seq., as amended by PL 103-305 (Aug. 23, 1994); The Federal Aviation Act of 1958
- The Control and Abatement of Aircraft Noise and Sonic Boom Act of 1968
- 49 U.S.C. 47101 et seq., as amended by PL 103-305 (Aug. 23, 1994); The Airport and Airway Improvement Act
- 49 U.S.C. 2101 et seq.; The Airport Noise and Capacity Act of 1990
- 49 U.S.C. 44715; The Noise Control Act of 1972
- 14 CFR part 150; Noise Control and Compatibility Planning for Airports Advisory Circular, 150/5020
- 14 CFR part 161; Notice and Approval of Airport Noise and Access Restrictions

2.2 Thresholds of Significance

Day Night Noise Level (DNL) is a cumulative measure of total sound energy. The DNL essentially represents an average of the sound levels at a location over a 24 hour period, with a 10 decibel (dB) weighting penalty added to all sounds occurring during nighttime hours between 10:00 p.m. and 7:00 a.m.. The 10 dB penalty represents the added intrusiveness of noise at nighttime because ambient sound levels during nighttime hours are typically about 10 dB lower than during daytime hours, and because of the annoyance associated with sleep disruption. (Appendix A describes the noise metrics used in this evaluation.)

In the Aviation Safety and Noise Abatement Act of 1979 (ASNA), Congress mandated that FAA develop an airport community noise metric that would be used by all federal agencies assessing or regulating aircraft noise. In 1980, the Federal Interagency Committee on Urban Noise (FICUN) initially established an annual average Day Night Noise Level (DNL) of 65 decibels (dBA) as the level of significant noise impact. The recommendations of the FICUN were adopted by the FAA in responding to Congress' requirement to select a noise metric. The FICUN land use compatibility recommendations were also embraced by the FAA in 14 CFR Part 150 (Table A), and serve as federal aircraft noise land use guidance.

This level of significance was subsequently re-examined and confirmed by the Federal Interagency Committee on Noise (FICON) in 1992. In accordance with this Federal policy, FAA Order 1050.1E states the following:

> A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dBA noise exposure when compared to the no action alternative for the same timeframe. For example, an increase from 63.5 dBA to 65 dBA is considered a significant impact.

Aircraft noise exposure is customarily evaluated relative to the probable effect on human activities characteristic of specific land uses. Federal guidelines (14 CFR Part 150 Table A) and thresholds for evaluating such effects on land use are outlined in Section 5.2.2 of the Environmental Impact Statement. All land uses are considered to be compatible with noise less than DNL 65, but only certain activities are compatible at levels greater than DNL 65. As discussed above, changes in DNL of 1.5 dB or more in noise sensitive areas exceeding DNL 65 are considered to be significant.

In addition to the threshold of significance discussed above, the 1992 FICON recommended that examination of noise levels between DNL 65 and 60 dBA be conducted if analysis shows that noise sensitive areas at or above DNL 65 dBA will have an increase of DNL 1.5 dB or more. This analysis should identify noise-sensitive areas between DNL 60-65 dBA having an increase of DNL 3 dB or more due to the proposed action. The FICON recommendations also state that the potential for mitigating noise in those areas should be considered, including consideration of the same range of mitigation options available at DNL 65 dBA and higher and eligibility for federal funding. As noted in FAA Order 1050.1E, the consideration of mitigation for noise impacts between DNL 60 and 65 "…is not to be interpreted as a commitment to fund or otherwise implement mitigation measures in any particular area."

One additional criterion was established by former FAA Notice N 7210.360, Noise Screening Procedure for Certain Air Traffic Actions above 3,000 Feet AGL. In this Notice, the FAA requires an assessment of changes in air traffic procedures that might result in a 5 dB increase in noise between 45 DNL and 60 DNL at noise-sensitive locations. These requirements are currently mentioned in FAA Order 1050.1E and the Air Traffic Noise Screening Model (ATNS) 2.0 User's Manual, January 1999.

All three of these criteria, a 1.5 dB or greater change in DNL to a level greater than 65 dB, a 3.0 dB or greater change in DNL between 60 and 65 dB, and a 5.0 dB or greater change in DNL from 45 to 60 dB were considered in this analysis.

3 NOISE MODELING

3.1 Introduction

Noise modeling was employed in this study to evaluate the noise contributions from taxi and hold operations on Taxiway November for the two queuing scenarios evaluated. The scenarios, called Free Flow and Limit All Jets, are described in more detail above in Section 1.2.1 and below in Sections 3.3.1 and 3.3.3. The modeling results were used to determine the significance of differences among the taxi operations scenarios. The modeling results are compared with measurements in Section 4.

The sections below describe the sound propagation model and the various inputs to the model that are necessary for accurate noise computations.

3.2 Sound Propagation Model

The SoundPLAN® computer model[5] was used to estimate sound propagation characteristics between each noise source and each prediction site. This program is a widely accepted tool for computing outdoor sound levels associated with ground-based noise sources. SoundPLAN® provides an estimate of sound levels at a distance from a specific noise source, or sources, taking into account:

- Specific characteristics of each noise source including its frequency spectrum and directivity characteristics.
- Terrain features including relative elevations of noise sources, receivers, and intervening objects.
- Ground effects due to areas of pavement, unpaved ground and water. Ground type affects sound propagation. Large acoustically "hard" areas, including the runways, taxiways and water, were specifically coded into the model.
- Shielding and reflections due to intervening buildings or other structures and diffracted paths around and over structures. Such objects were not included in this modeling effort, since none exist between the taxiway and the NMS sites.
- Atmospheric effects on sound propagation. The SoundPLAN® model includes several different methods of accounting for atmospheric effects on sound propagation. For this evaluation, the model's implementation of ISO Standard 9613-2[6] was used. ISO 9613-2 specifies use of "wind direction . . . with the wind blowing from the source to the receiver, and wind speed between approximately 1 m/s and 5 m/s ..." The equations in the Standard "also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights." Use of this Standard provides a conservatively high estimate of community sound levels caused by ground-based airport sources. In addition, because the higher sound levels that exist over time have greater influence on the DNL than the lower levels, the Standard also applies to "a variety of meteorological conditions as they exist over months or years."

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[5] SoundPLAN® Version 6.2 is the current release and was used in the evaluation. Documentation provided in SoundPLAN® User's Manual, Braunstein + Berndt GmbH, January 2004.

[6] ISO Standard 9613-2, "Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation," International Organization for Standardization, Geneva, 1996.

The SoundPLAN® model is more appropriate for evaluation of aircraft ground operations than the FAA's Integrated Noise Model (INM), which is intended primarily for the evaluation of aircraft flight operations. While the INM can be used to model taxi operations, it is a very crude tool for this purpose. For example, both the frequency and directivity characteristics of the aircraft source data in the INM database are derived from measurements conducted with engines at high power settings. It is well known that both the frequency and directivity characteristics of aircraft engine noise are very different at idle/taxi power settings. By using SoundPLAN and aircraft noise emissions data collected at idle/taxi power settings, noise modeling is much more precise. Also, the INM does not incorporate any building or terrain shielding, or variation in ground type (such as the intervening water between the taxiway and shoreline homes in East Boston and Winthrop), so these characteristics, which are important for ground-based noise sources cannot be modeled with INM.

3.3 Model Input

The noise model input falls into three major categories: model geometry, noise source characteristics and operations. The geometry input consists of source and receiver locations, ground types, and topography. The source data include the levels, spectra, and directional characteristics of each aircraft used within the model. The operational input is the number of minutes that each aircraft type spends idling at or taxiing through a particular location. The following sections discuss each of these input types in detail.

3.3.1 Source-Receiver Geometry

SoundPLAN has the ability to model many details of the acoustical environment. Figure 1 shows some of the features of the environment that were entered into the noise model: source and receiver locations, ground types, and terrain. To quantify the amount of time spent by aircraft moving or idling on Taxiway November, the taxiway was divided into fifteen segments north of Runway 15R. All but one segment is 80 meters long, the approximate length of an average aircraft. Each *segment* was modeled as a discrete source *location*, labeled N_0 to N_14 as shown in. The figure also shows the orientation of the aircraft at each location. SoundPLAN calculated noise levels for these sources at four receiver points. These points are located at Logan's permanent noise monitors NMS 7, 9, 10, and 12. The characteristics of the ground affect sound propagation. Hard ground tends to reflect sound while soft ground between a source and receiver can lower sound levels at the receiver. The default ground type in SoundPLAN is soft ground. Two types of hard, reflective ground were coded into the model for this study: water and pavement. Both are shown in. Massport provided drawing files that included the locations of the runways and taxiways and they provided the coordinates of the receiver positions. Waterline and other terrain features were obtained from publicly-available 3-meter elevation data.

3.3.2 Source Characteristics

Source Groupings

The modeling effort required each aircraft type in the FAA log to be matched to specific noise source emission data within SoundPLAN. Source data for taxiing and idling aircraft were based upon measurement data from similar previous studies and from manufacturers. The aircraft were divided into five representative categories based on the maximum gross takeoff weight listed in

Figure 1 Logan Taxiway Noise Model Objects

the INM 6.1 standard database. Emission level data for one representative aircraft type was then used to characterize each of the categories. The five groups and the representative aircraft types were:

- Jumbo Air Carrier – Boeing 747
- Heavy Air Carrier – Boeing 767
- Large Air Carrier – Boeing 737-300
- Regional and Corporate Jets – Canadair Regional Jet
- Propeller Aircraft – Beech 1900

Table 1 shows the groupings for all aircraft types listed within the taxi operations data logged by the FAA. Table 5 in Appendix C of the Operations report (Attachment A to the main report) lists details of the associated aircraft manufacturer, model number and noise group for each of the types listed below.

Table 1 Source Groupings

Jumbo Air Carrier	Heavy Air Carrier	Large Air Carrier	Corporate and Regional Jet	Propeller Aircraft
A332	A306	A319	ASTR	B190
A333	A310	A320	BE40	BE20
A343	B762	A321	C525	BE58
B744	B763	B462	C550	BE9L
B772	B764	B712	C560	C402
DC10	DC8Q	B722	C56X	C421
		B727	C750	DH8A
		B72Q	CL64	PA31
		B732	CRJ1	PA32
		B733	CRJ2	SF34
		B734	E135	
		B735	E145	
		B737	F2TH	
		B738	F900	
		B739	FA50	
		B752	GALX	
		DC93	GLF2	
		DC95	GLF4	
		DC9Q	H25B	
		MD80	H25C	
			HS25	
			J328	
			LJ35	
			LJ60	
			LR45	

Source Noise Emission Levels

Each source within SoundPLAN is represented by a 1/3-octave band spectrum at each angle for which directivity information is provided. Appropriate source data at this level of detail is not provided in the FAA's Integrated Noise Model (INM) database for aircraft ground operations. The INM includes "spectral classes" for aircraft, but they are designated only for higher-powered arrival and departure operations. Spectrum shapes are significantly different at idle and taxi power settings. A further limiting factor with the INM data is that a single directivity pattern is used for all aircraft at all frequencies.

Therefore, to model the noise from operations on Taxiway November with the greatest accuracy possible, HMMH used spectra and directivity information from measurements that have been conducted at low power settings for similar ground operations noise studies.

Spectra and directivity for the Jumbo Air Carrier (Boeing 747) and A-weighted sound levels for the Heavy Air Carrier (Boeing 767) were measured by HMMH as the aircraft taxied at Anchorage International Airport in Alaska. Because the engines are similar in the Boeing 767 and 747, the spectrum shape and directivity pattern of the 747 were adjusted to match the measured A-weighted levels of the 767 to obtain spectra and directivity for that aircraft. The Large Air Carrier (Boeing 737-300), measured by Boeing, and the Propeller Aircraft (Beech 1900) measured by Wyle Laboratories at General Mitchell International Airport in Milwaukee, were both measured with a single engine operating at idle power over a 180-degree semi-circle in 10-degree increments, from nose to tail. In the model, these data were mirrored for the opposite side of the aircraft and increased by 3 dB to account for a second engine. The Corporate/Regional Jet (Canadair Regional Jet) was measured with both engines operating at idle power also over a 180-degree semi-circle, by HMMH at Mitchell Airport in Milwaukee.

Figure 2 illustrates the level of detail in the SoundPLAN source input. The left side of the graphic shows the sound power spectrum for a Canadair Regional Jet at idle power. Each green bar represents the sound power that the jet emits within a particular 1/3 octave band. The red bar at left is the total sound power. The blue bar is the sound power in the 80 Hz band. The plot on the right shows the directivity of the 80 Hz band in ten-degree increments. It shows that at this particular frequency the levels are much higher on each side of the plane (90 and 270 degrees) than in front or behind (0 and 180 degrees). Each 1/3 octave band for each source has its own unique directivity pattern within SoundPLAN, taken from measurements.

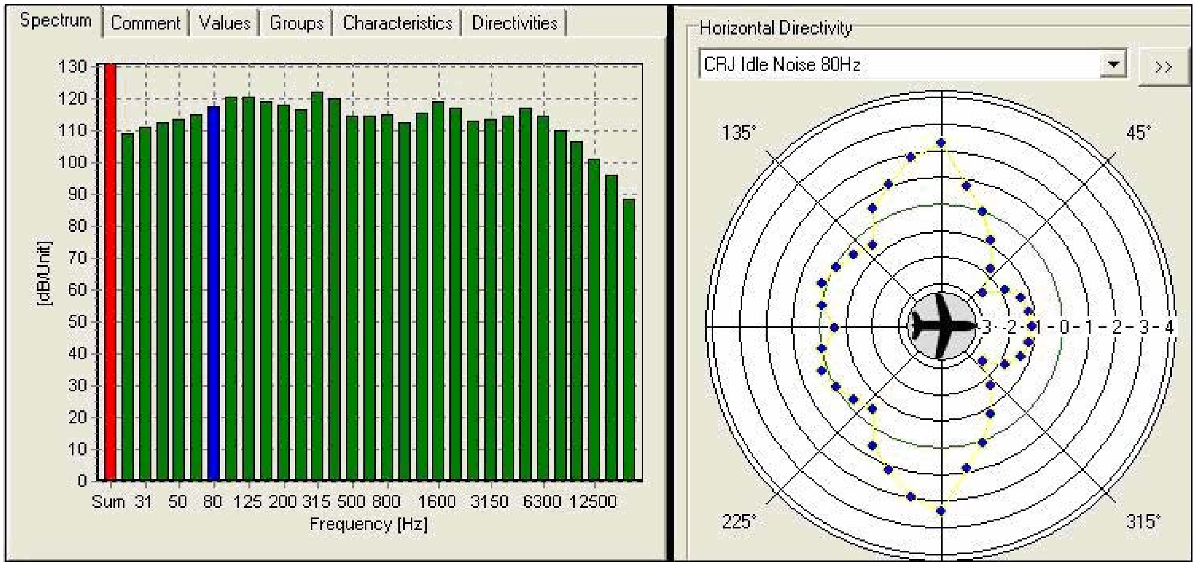

Figure 2 Example SoundPLAN Spectrum and Directivity Plot

Table 2 Summarizes the source level input by listing the A-weighted sound levels at a distance of 200 feet for each source by angle from the front of the aircraft, in 10-degree increments.

Table 2 Taxi Source A-weighted Emission Levels

Aircraft Group	Angle / A/C Type	A-Weighted Sound Levels at 200 feet by Angle from Inlet in Degrees (dBA)																		
		0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Jumbo	B747	89	89	89	89	89	89	89	89	89	89	87	86	85	83	83	83	83	83	83
Heavy	B767	87	87	87	87	87	87	87	87	87	87	85	84	83	81	81	81	81	81	81
Large	B737-300	90	90	90	93	90	87	85	84	84	84	86	90	93	92	90	87	84	84	84
RJCJ	CRJ	86	87	88	87	86	84	83	82	82	81	81	81	81	81	81	81	81	79	77
Prop	B190	88	88	88	88	82	80	80	78	78	77	78	78	78	77	80	78	70	65	60

Appendix B provides more information on the source characteristics of each aircraft in tabular and graphical form. Section B.1 provides tables of the noise emissions by one-third octave band, and Section B.2 shows graphical plots of the A-weighted directivity patterns for each of the five aircraft types.

3.3.3 Taxi Operations

Complete details of the taxi operations incorporated into the noise model are given in Attachment A to the main report, entitled "Operational Analysis of Taxi Queuing Alternatives for Taxiway November at Logan International Airport." This section provides only a summary as it relates to the noise analysis.

As shown above, the taxiway was divided into fifteen locations/segments, numbered N_0 to N_14. Based on the FAA 24-hour log of activity on Taxiway November, and for each of these segments, the taxi and queue time model (described in the Attachment A Operations report) computed the number of minutes that each of 69 aircraft types spent within that segment during each hour of the day.

For computation of DNL in the model, the total minutes of taxi time for each aircraft type at each location was condensed by expressing the taxi time in "equivalent minutes." First, the minutes of taxi time that occurred at night between 10 PM and 7 AM were multiplied by 10, such that each minute of nighttime operation was equivalent to 10 daytime minutes, as required for DNL computations. These "weighted" nighttime minutes were then added to all of the daytime minutes for a total 24 hours of "equivalent minutes" of taxi operations for each aircraft type at each taxi segment/location. Table 3 presents the sums of all taxi minutes over aircraft type and location to show the total daytime, nighttime, total and total equivalent minutes for the two alternatives. These times have been scaled up from the FAA logs by 30% to represent a worst-case busy-day scenario. The Attachment A Operations report shows the breakdown of taxi/queue time by taxiway segment, time of day, aircraft noise group, and, in the report's appendix, by aircraft type.

Table 3 Total Taxi Time by Alternative

Period	Total Taxi/Queue Time (minutes)	
	Free Flow	Limit All Jets
Day	4,191	4,180
Night	261	261
Day plus night	4,452	4,441
Equivalent	6,805	6,794

The total number of taxi minutes is very slightly different in the two scenarios. This is because in the limiting scenario, when the queue is at its longest, an aircraft that would normally wait near the end of Taxiway November in location N_14 is held short of (south of) Runway 15R. Noise contributions from taxi and hold locations south of Runway 15R were not modeled because the distance to the community positions is large, and the contributions would be insignificant relative to those from the closer positions. However, to the extent that aircraft on the far side of Runway 15R could contribute to the DNL at the receiver locations, this study will overestimate the benefit of the queuing alternatives.

4 NOISE MODEL VALIDATION – COMPARISONS WITH MEASUREMENTS

The noise model computations were compared with measurements at the monitor sites by examining brief periods when noise from Taxiway November controls the sound level measured at the closest monitor sites, NMS 12 and 10.

A modest program of noise measurements and aircraft queue logging was undertaken to provide limited validation of the noise prediction model. During four days in June 2004, when runways 22L and 22R were in use for departures and queue lengths were expected to be long (between 8 AM and 10 AM), NMS 12 (and NMS 10 for some days) was set to acquire continuous one-second samples of the L_{eq} sound level (called "time histories"). At the same time, FAA controllers in the Boston Tower logged the queuing activities on Taxiway November, and observers at NMS 12 (the site closest to Taxiway November) logged time periods when noise from Taxiway November appeared to be the dominant source of noise.

Figure 3 presents a graph of the time history of the one-second L_{eq} sound levels recorded at NMS 12 from 8:45 to 9:05 AM on June 25, 2004. Periods of time when the site observer logged Taxiway November as the dominant noise source are shown in red; they are one to two minutes long. During

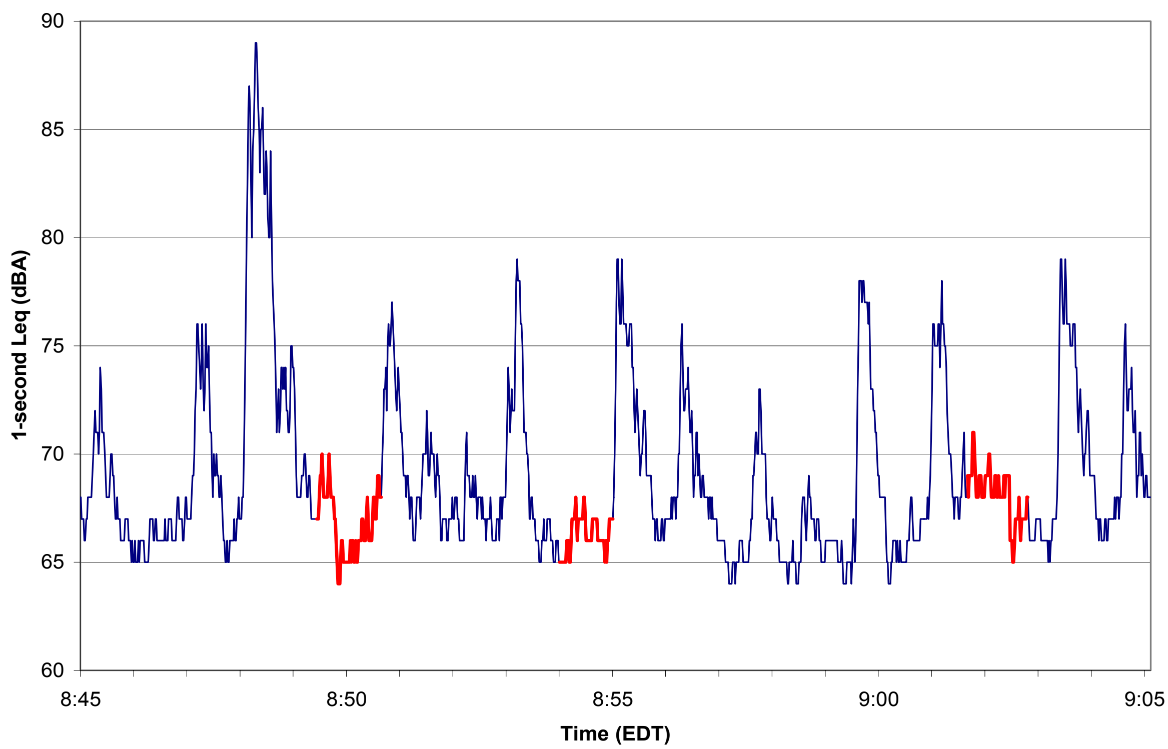

Figure 3 Noise Monitor 12 Time History Plot for June 25, 2004

those times, between 9 and 11 aircraft were in the queue along the taxiway, as documented by the FAA observer in the tower. The graph indicates that the A-weighted noise level at NMS 12 ranged between about 64 and 71 dBA while the taxiway was the dominant noise source. The peak events shown in the graph are all from departing aircraft on Runways 22L and 22R, which result in maximum sound levels between about 73 dBA and 89 dBA.

For ten periods in June of 2003 identified in the observer logs as dominated by noise from Taxiway November, the average A-weighted noise level (Leq) from the monitoring data was computed. The periods were typically between one and two minutes long. The FAA queue logs were used to determine the types and locations of aircraft along Taxiway November during each of the ten time periods. Aircraft were then modeled in locations along the taxiway starting at N_0, with each aircraft occupying a single location and no gaps between aircraft. The model computed the sound level at NMS 12 and NMS 10 for the mix of aircraft during each period.

Weather data were collected for the ten observation periods, since wind conditions affect sound levels from ground-based noise sources quite significantly. As described in Section 3.2, the model is expected to be at its most accurate under slight downwind conditions. The standard used in the model, ISO 9613-2, usually computes higher values than those measured under upwind conditions – when the wind is blowing from the receiver toward the source. The magnitude of the differences depends on several factors, including distance, source and receiver height, and ground type. A justification for using a model that predicts best for downwind conditions is that over long periods of time with varying wind conditions, the louder levels that occur in the downwind condition tend to dominate the average sound level (DNL). Also, there is frequently a downwind component towards at least some of the residential locations along the East Boston/Winthrop shoreline whenever aircraft are using Taxiway November to depart from Runways 22R or 22L.

Table 4 shows a comparison of the measured and modeled L_{eq} values for the ten periods, along with other pertinent information. The table organizes the periods by wind direction and then in chronological order. In periods when the monitor was upwind, the computed level was 7 dB to 10 dB higher than the measured level. During periods when the noise monitor was downwind, the agreement was much better as expected, with differences from 0 dB to 3 dB. These results suggest the model produces conservatively high computed values, appropriate for noise impact evaluation.

Table 4 Comparison of Short-term Measured and Modeled Taxiway Noise

Wind Conditions	Date	Time (EDT)	Noise Monitor	Measured Leq (dBA)	Computed Leq (dBA)	Computed minus Measured (dB)
direct upwind	23 Jun 04	8:38	12	60	70	10
direct upwind	23 Jun 04	9:22	12	63	73	10
upwind	30 Jun 04	8:44	12	66	73	7
upwind	30 Jun 04	8:54	12	64	71	7
upwind	30 Jun 04	9:03	12	63	71	8
crosswind	25 Jun 04	8:54	12	66	70	4
crosswind	25 Jun 04	9:02	12	68	74	6
slight downwind	30 Jun 04	8:44	10	71	71	0
slight downwind	30 Jun 04	8:54	10	66	69	3
slight downwind	30 Jun 04	9:03	10	69	70	1

5 RESULTS AND CONCLUSIONS

Table 5 shows the calculated DNL values at the four receiver locations for the Free Flow and Limit All Jets scenarios, along with the differences in DNL. There are no *increases* in noise from the Free Flow to the Limit All Jets Alternative, and the computed reductions are very small. The Limit All Jets Alternative averages less than 0.1 decibels quieter than the Free Flow Alternative. Appendix C provides graphs of partial DNL values by location (the contribution to the total DNL from each of the taxi/queue locations modeled) for each alternative at NMS 10 and NMS 12.

Table 5 DNL Results from Taxi Noise Model

Receiver	Free Flow DNL (dBA)	Limit All Jets	
		Total DNL (dBA)	Change from Free Flow
NMS 7	62.4	62.4	0.0
NMS 9	67.1	67.0	-0.1
NMS 10	66.5	66.5	0.0
NMS 12	68.9	68.9	0.0

These differences are all much less than FAA's 1.5-decibel threshold of significance, so no significant reduction in noise impact is expected from implementing an alternative that limits aircraft queuing.

From the standpoint of what may be perceived by the nearby residents, other studies[7] have suggested that changes in DNL between 0 and 2 decibels "may be perceived." Changes between 2 and 5 decibels are "generally perceived." The changes in noise exposure with the alternative queuing scenarios fall at the low end of the range of what 'may be perceived" by nearby residents.

Also, even as small as these improvements may be, the results given above overestimate the benefits of the alternatives for three different reasons:

1. The differences are compared without considering arriving and departing aircraft, which contribute more to the DNL than taxi operations in three of the four community areas.
2. The noise computation model uses downwind propagation assumptions, which is likely to overstate taxi operations noise in the community areas near NMS 12 and NMS 10 (East Boston Yacht Club, Constitution Beach, and the western end of Bayswater Street).
3. The modeling was conducted for a day when Runways 22R and 22L were in use exclusively for departures, therefore, the effect on annual average DNL would be less than it is for the 24-hour period that was modeled.

[7] Miller, Nicholas P., Henning E. von Gierke, Kenneth McK. Eldred, "Final Report No. 26, Impact Assessment Guidelines for the Effects of Noise on People," Harris Miller Miller & Hanson Inc. Report No. 291060.01, prepared for Transport Canada, Major Crown Projects, L.B.P.I.A., October 1991.

We conclude from this analysis that, while noise from the Limit All Jets alternative is likely to be very slightly less than that from the Free Flow Alternative in one of the community areas, the noise benefits are minimal at best.

APPENDIX A DESCRIPTION OF NOISE METRICS

To assist reviewers in interpreting the complex noise metrics used in evaluating airport noise, we present below an introduction to relevant fundamentals of acoustics and noise terminology.

A.1 Introduction to Acoustics and Noise Terminology

Five acoustical descriptors of noise are introduced here in increasing degree of complexity:

- Decibel, dB;
- A-weighted decibel, dBA;
- Sound Exposure Level, SEL;
- Equivalent Sound Level, Leq; and
- Day-Night Average Sound Level, DNL.

These noise metrics form the basis for the majority of noise analysis conducted at most airports throughout the U.S.

A.1.1 Decibel, dB

All sounds come from a sound source -- a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source is transmitted through the air in sound waves -- tiny, quick oscillations of pressure just above and just below atmospheric pressure. These oscillations, or sound pressures, impinge on the ear, creating the sound we hear.

Our ears are sensitive to a wide range of sound pressures. Although the loudest sounds that we hear without pain have about one million times more energy than the quietest sounds we hear, our ears are incapable of detecting small differences in these pressures. Thus, to better match how we hear this sound energy, we compress the total range of sound pressures to a more meaningful range by introducing the concept of sound pressure level.

Sound pressure levels are measured in decibels (or dB). Decibels are logarithmic quantities reflecting the ratio of the two pressures, the numerator being the pressure of the sound source of interest, and the denominator being a reference pressure (the quietest sound we can hear).

The logarithmic conversion of sound pressure to sound pressure *level* (SPL) means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels on the order of 30 to 100 dB.

Because decibels are logarithmic quantities, combining decibels is unlike common arithmetic. For example, if two sound sources each produce 100 dB operating individually and they are then operated together, they produce 103 dB -- not the 200 decibels we might expect. Four equal sources operating simultaneously produce another three decibels of noise, resulting in a total sound pressure level of 106 dB. For every doubling of the number of equal sources, the sound pressure level goes up another three decibels. A tenfold increase in the number of sources makes the sound pressure level go up 10 dB. A hundredfold increase makes the level go up 20 dB, and it takes a thousand equal sources to increase the level 30 dB.

If one noise source is much louder than another, the two sources operating together will produce virtually the same sound pressure level (and sound to our ears) that the louder source would produce alone. For example, a 100 dB source plus an 80 dB source produce approximately 100 dB of noise when operating together (actually, 100.04 dB). The louder source "masks" the quieter one. But if the quieter source gets louder, it will have an increasing effect on the total sound pressure level such that, when the two sources are equal, as described above, they produce a level three decibels above the sound of either one by itself.

Conveniently, people also hear in a logarithmic fashion. Two useful rules of thumb to remember when comparing sound levels are: (1) a 6 to 10 dB increase in the sound pressure level is perceived by individuals as being a doubling of loudness, and (2) changes in sound pressure level of less than about three decibels are not readily detectable outside of a laboratory environment.

A.1.2 A-Weighted Decibel, dBA

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of the sound pressure oscillations as they reach our ear. When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to determine how much is low-frequency noise, how much is middle-frequency noise, and how much is high-frequency noise. This breakdown is important for two reasons:

(1) People react differently to low-, mid-, and high-frequency noise levels. This is because our ear is better equipped to hear mid and high frequencies but is quite insensitive to lower frequencies. Thus, we find mid- and high-frequency noise to be more annoying.

(2) Engineering solutions to a noise problem are different for different frequency ranges. Low-frequency noise is generally harder to control.

The normal frequency range of hearing for most people extends from a low frequency of about 20 Hz to a high frequency of about 10,000 to 15,000 Hz. People respond to sound most readily when the predominant frequency is in the range of normal conversation, typically around 1,000 to 2,000 Hz. Acousticians have developed several filters which roughly match this sensitivity of our ear and thus help us to judge the relative loudness of various sounds made up of many different frequencies. The so-called A-weighting network, does this best for most environmental noise sources. Sound pressure levels measured through this filter are referred to as A-weighted sound levels (measured in A-weighted decibels, or dBA).

The A-weighting network significantly discounts those parts of the total noise that occur at lower frequencies (those below about 500 Hz) and also at very high frequencies (above 10,000 Hz) where we do not hear as well. The network has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz where our hearing is most sensitive. Because this network generally matches our ears' sensitivity, sounds having higher A-weighted sound levels are judged to be louder than those with lower A-weighted sound levels, a relationship which otherwise might not be true. It is for this reason that A-weighted sound levels are normally used to evaluate environmental noise sources. Figure 4 presents typical A-weighted sound levels of several common environmental sources.

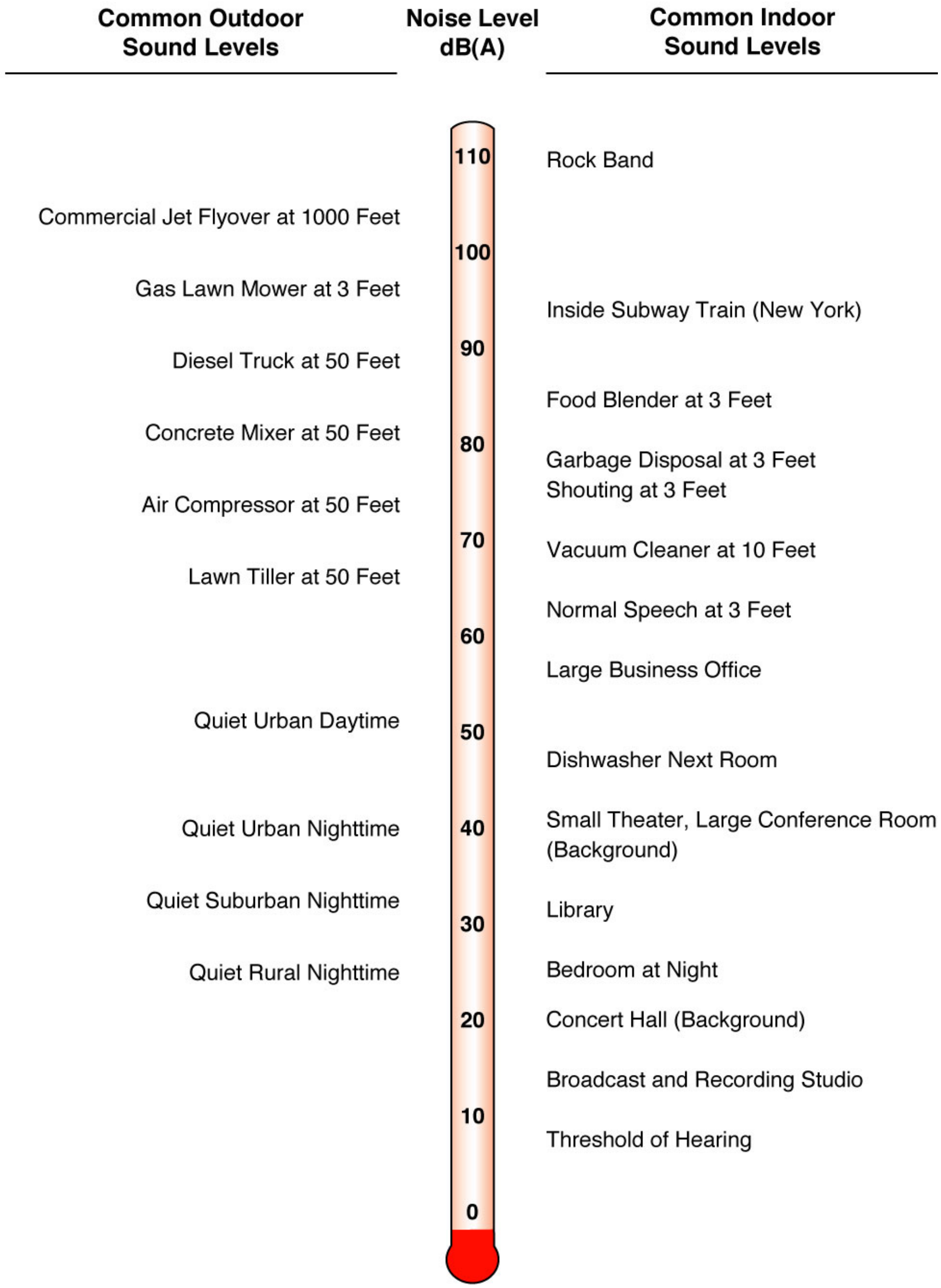

Figure 4 Common Environmental Sound Levels, in dBA

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as an aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance (though even the background varies as birds chirp, the wind blows, or a vehicle passes by). This is illustrated in Figure 5.

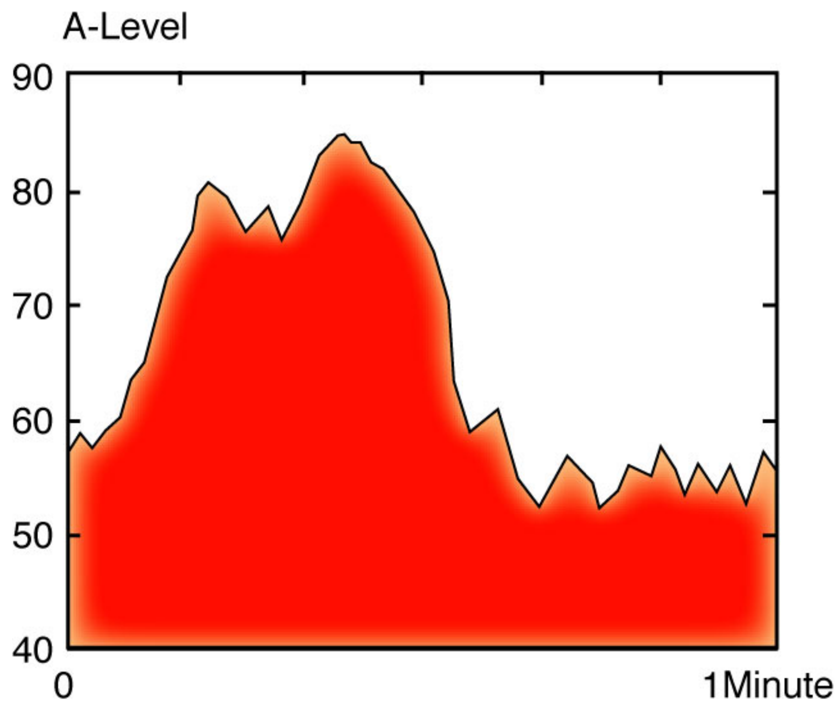

Figure 5 Variation in the A-weighted Sound Level Over Time

Because of this variation, it is often convenient to describe a particular noise "event" by its maximum sound level, abbreviated as L_{max}. In Figure 5, the L_{max} is approximately 85 dBA. However, the maximum level describes only one dimension of an event; it provides no information on the cumulative noise exposure generated by a sound source. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose."

A.1.3 Sound Exposure Level, SEL

The most common measure of cumulative noise exposure for a single aircraft fly-over is the Sound Exposure Level, or SEL. SEL is an accumulation of the sound energy over the duration of a noise event. The lightly shaded area in Figure 6 illustrates the portion of the sound energy included in this dose. To account for the variety of durations that occur among different noise events, the noise dose is normalized (standardized) to a one-second duration. This normalized dose is the SEL; it is shown as the darkly shaded area in Figure 6. Mathematically, the SEL is the summation of all the noise energy compressed into one second.

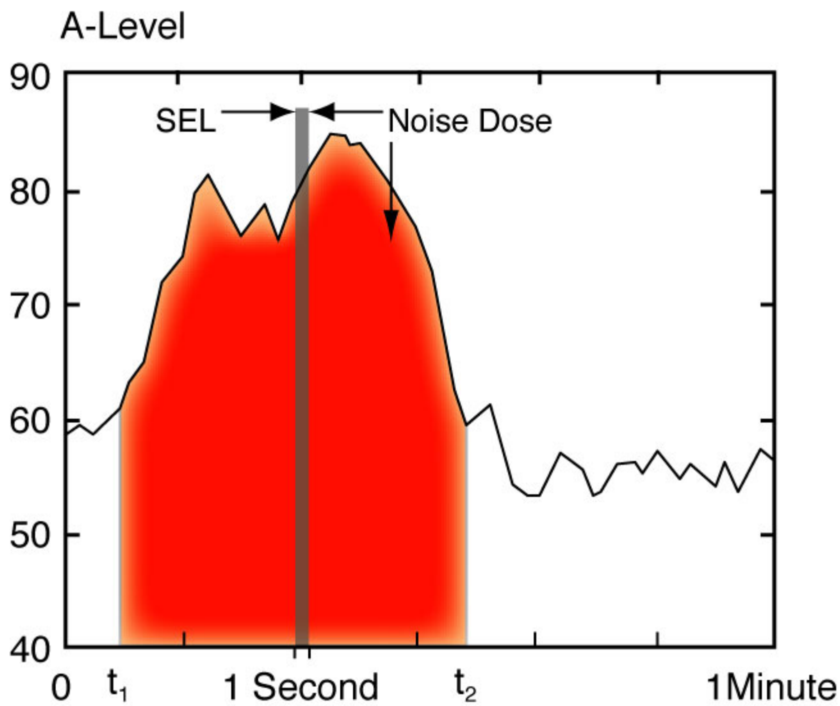

Figure 6 Sound Exposure Level

Note that because the SEL is normalized to one second, it will almost always be larger in magnitude than the maximum A-weighted level for the event. In fact, for most aircraft overflights, the SEL is on the order of 7 to 12 dBA higher than the L_{max}. Also, the fact that it is a cumulative measure means that not only do louder fly-overs have higher SEL than do quieter ones, but also fly-overs with longer durations have greater SEL than do shorter ones.

With this metric, we now have a basis for comparing noise events that generally matches our impression of the sound -- the higher the SEL, the more annoying it is likely to be. In addition, SEL provides a comprehensive way to describe a noise event for use in modeling noise exposure. Computer noise models base their computations on these SELs.

A.1.4 Equivalent Sound Level, Leq

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an eight-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level. This is illustrated in Figure 7. The equivalent level is, in a sense, the total sound energy that occurred during the time in question, but spread evenly over the time period. It is a way of assigning a single number to a time-varying sound level. Since L_{eq} includes all sound energy, it is strongly influenced by the louder events.

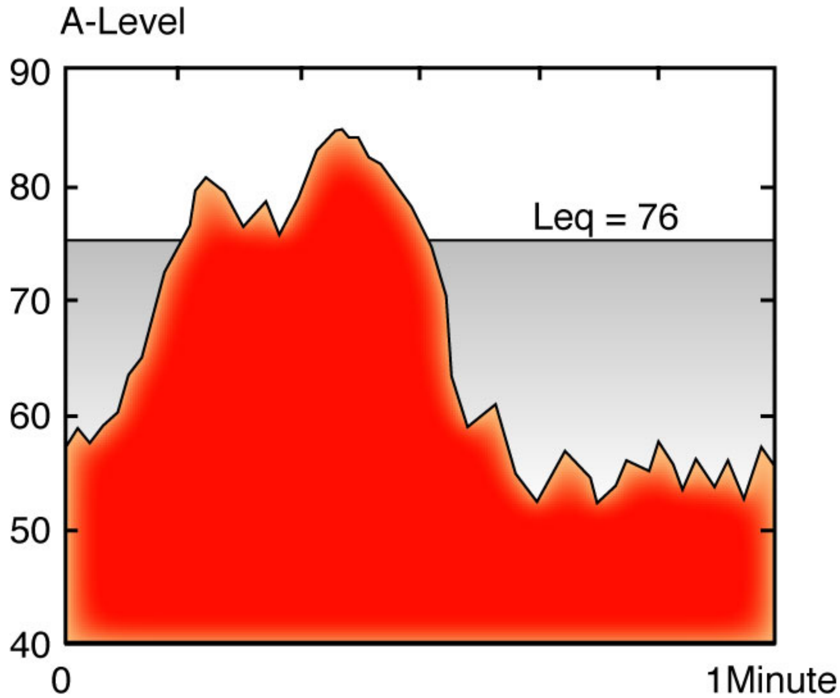

Figure 7 Example of a 1-minute Equivalent Sound Level

As for its application to airport noise issues, L_{eq} is often presented for consecutive one-hour periods to illustrate how the hourly noise dose rises and falls throughout a 24-hour period as well as how certain hours are significantly affected by a few loud aircraft.

A.1.5 Day-Night Average Sound Level, DNL

In the previous sections, we have been addressing noise measures that account for the moment-to-moment or short-term fluctuations in A-weighted levels as sound sources come and go affecting our overall noise environment. The Day-Night Average Sound Level (DNL) represents a concept of noise dose as it occurs over a 24-hour period. It is the same as a 24-hour L_{eq}, with one important exception; DNL treats nighttime noise differently from daytime noise. In determining DNL, it is assumed that the A-weighted levels occurring at night (10 p.m. to 7 a.m.) are 10 dB louder than they really are. This 10 dB penalty is applied to account for greater sensitivity to nighttime noise, and the fact that events at night are often perceived to be more intrusive because nighttime ambient noise is less than daytime ambient noise.

Earlier, we illustrated the A-weighted level due to an aircraft event. The example is repeated in the top frame of Figure A.5. The level increases as the aircraft approaches, reaching a maximum of 85 dBA, and then decreases as the aircraft passes by. The ambient A-weighted level around 55 dBA is due to the background sounds that dominate after the aircraft passes. The shaded area reflects the noise dose that a listener receives during the one-minute period of the sample.

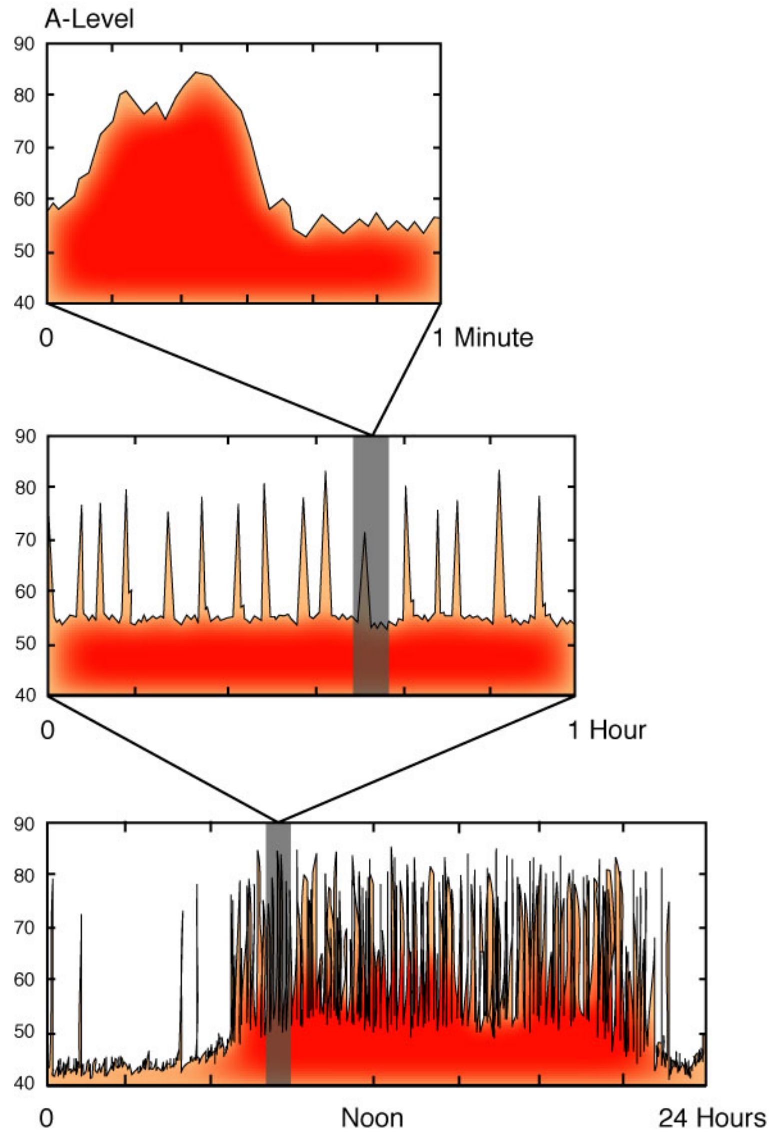

Figure 8 A-weighted Level Fluctuations and Noise Dose

The center frame of Figure 8 includes this one-minute interval within a full hour. Now the shaded area represents the noise dose during that hour when sixteen aircraft pass nearby, each producing a single event dose represented by an SEL. Similarly, the bottom frame includes the one-hour interval within a full 24 hours. Here the shaded area represents the noise dose over a complete day. Note that several overflights occur at night, when the background noise drops some 10 decibels, to approximately 45 dBA.

Values of DNL are normally measured with standard monitoring equipment or are predicted with computer models. Measurements are practical for obtaining DNL values for only relatively limited numbers of locations, and, in the absence of a permanently installed monitoring system, only for relatively short time periods. Thus, most airport noise studies utilize computer-generated estimates of DNL, determined by accounting for all of the SEL from individual aircraft operations that comprise the total noise dose at a given location on the ground. This principle is used in all airport noise modeling.

Computed values of DNL are usually depicted as noise contours that are lines of equal exposure around an airport (much as topographic maps have contour lines of equal elevation). The contours usually reflect long-term (annual average) operating conditions, taking into account the average flights per day, how often each runway is used throughout the year, and where over the surrounding communities the aircraft normally fly.

Figure 9 presents a representative sample of DNL (denoted L_{dn} in the figure) measured at various locations in the U.S.

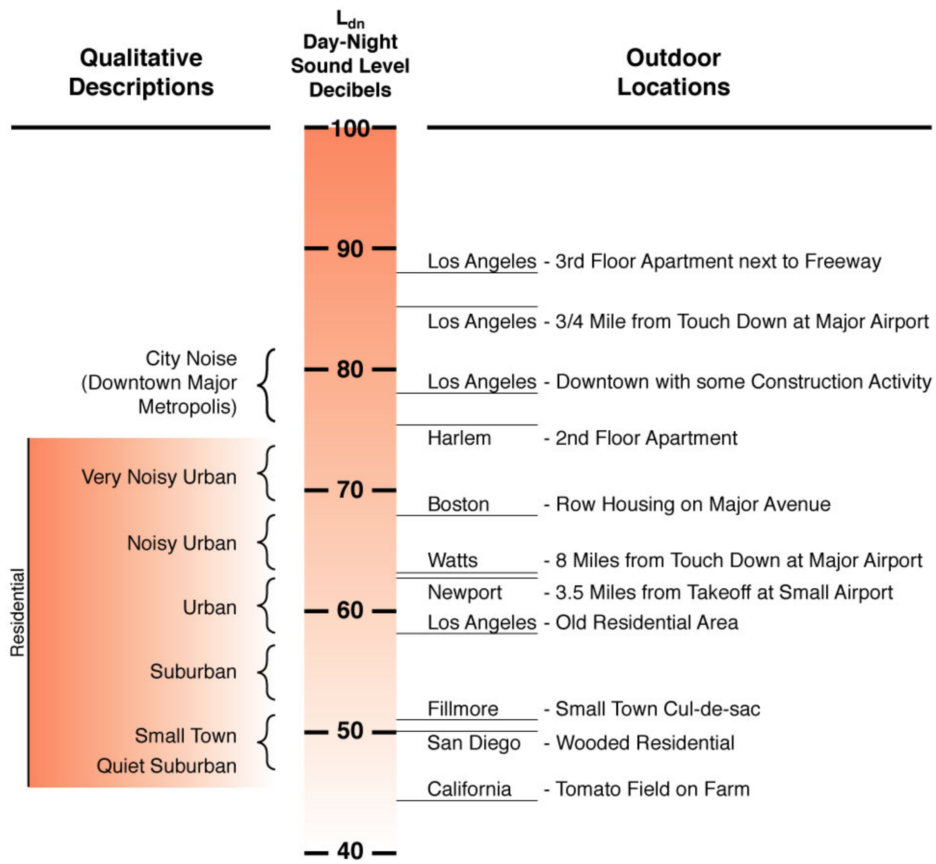

Figure 9 Representative Examples of Day-Night Average Sound Levels

Source: United States Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, March 1974, p.14

APPENDIX B AIRCRAFT NOISE EMISSION DETAILS

B.1 Tables of Aircraft Noise Emissions

This section provides five tables of the noise emission levels used in the modeling for each of the five aircraft groups modeled. Each table provides the noise emission level in decibels (un-weighted) in each 1/3-octave band at each of 19 angles in 10-degree increments from the front of the aircraft. Each decibel value is normalized to a distance of 200 feet from the aircraft engine.

As mentioned in the body of the report, the Large Air Carrier (Boeing 737-300) was measured by Boeing, and the Propeller Aircraft (Beech 1900) was measured by Wyle Laboratories at General Mitchell International Airport in Milwaukee. Both sets of measurements were conducted with a single engine operating at idle power over a 180-degree semi-circle in 10-degree increments, from nose to tail. In the model, these data were mirrored for the opposite side of the aircraft and increased by 3 dB to account for a second engine. The Corporate/Regional Jet (Canadair Regional Jet) was measured by HMMH at Mitchell Airport in Milwaukee, with both engines operating at idle power and also over a 180-degree semi-circle.

The spectra and directivity for the Jumbo Air Carrier (Boeing 747) and A-weighted sound levels for the Heavy Air Carrier (Boeing 767) were measured by HMMH as the aircraft taxied at Anchorage International Airport in Alaska. Because the engines are similar in the Boeing 767 and 747, the spectrum shape and directivity pattern of the 747 were adjusted to match the measured A-weighted levels of the 767 to obtain spectra and directivity for that aircraft. Three spectra were taken from the points where the aircraft were at 45-degree, 90-degree and 135-degree positions relative to the microphone. Since the SoundPLAN model requires data at all angles from each source, the spectrum measured at the 45-degree position was applied at the 0, 10, 20, 30, and 40-degree positions. Linear interpolation in each 1/3 octave band was performed between the measured levels at the 45-degree and 90-degree positions to develop the spectra for the 50, 60, 70, and 80-degree positions. Interpolation was also used to develop spectra for the angles between 90 degrees and 135 degrees. Then, for angles between 135 and 180 degrees, the spectrum measured for 135 degrees was applied.

Table 6 Jumbo Air Carrier (Boeing 747) Detailed Source Levels at 200 feet

1/3 Ocatave Band (Hz)	Sound Pressure Level by Angle from Front of Aircraft (dB)																		
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
12.5	55.4	55.4	55.4	55.4	55.4	56.3	58.1	59.8	61.6	63.3	64.2	65.1	66.0	66.9	67.3	67.3	67.3	67.3	67.3
16	59.8	59.8	59.8	59.8	59.8	60.6	62.1	63.7	65.2	66.7	66.8	66.8	66.9	66.9	66.9	66.9	66.9	66.9	66.9
20	61.0	61.0	61.0	61.0	61.0	61.2	61.5	61.9	62.2	62.5	63.8	65.1	66.4	67.7	68.3	68.3	68.3	68.3	68.3
25	61.8	61.8	61.8	61.8	61.8	62.3	63.2	64.2	65.1	66.0	67.3	68.6	69.8	71.1	71.7	71.7	71.7	71.7	71.7
31	64.6	64.6	64.6	64.6	64.6	65.5	67.1	68.7	70.4	72.0	71.9	71.8	71.8	71.7	71.6	71.6	71.6	71.6	71.6
40	69.5	69.5	69.5	69.5	69.5	69.9	70.5	71.2	71.9	72.5	72.5	72.4	72.4	72.4	72.3	72.3	72.3	72.3	72.3
50	71.3	71.3	71.3	71.3	71.3	71.8	72.7	73.7	74.6	75.5	76.4	77.3	78.2	79.1	79.5	79.5	79.5	79.5	79.5
63	74.0	74.0	74.0	74.0	74.0	74.2	74.7	75.1	75.5	75.9	77.4	78.9	80.3	81.8	82.5	82.5	82.5	82.5	82.5
80	78.4	78.4	78.4	78.4	78.4	78.9	79.8	80.8	81.7	82.6	82.1	81.6	81.0	80.5	80.2	80.2	80.2	80.2	80.2
100	67.3	67.3	67.3	67.3	67.3	67.7	68.3	69.0	69.7	70.3	70.5	70.6	70.7	70.9	70.9	70.9	70.9	70.9	70.9
125	64.0	64.0	64.0	64.0	64.0	64.5	65.5	66.4	67.4	68.3	69.1	70.0	70.8	71.6	72.0	72.0	72.0	72.0	72.0
160	66.6	66.6	66.6	66.6	66.6	67.0	67.6	68.2	68.9	69.5	69.9	70.2	70.6	71.0	71.1	71.1	71.1	71.1	71.1
200	65.5	65.5	65.5	65.5	65.5	66.1	67.2	68.3	69.4	70.5	70.9	71.4	71.8	72.2	72.4	72.4	72.4	72.4	72.4
250	63.4	63.4	63.4	63.4	63.4	64.1	65.4	66.7	68.0	69.3	70.2	71.0	71.9	72.7	73.1	73.1	73.1	73.1	73.1
315	63.5	63.5	63.5	63.5	63.5	64.4	66.2	67.9	69.7	71.4	71.2	71.0	70.8	70.6	70.5	70.5	70.5	70.5	70.5
400	66.2	66.2	66.2	66.2	66.2	67.1	68.9	70.6	72.4	74.1	73.8	73.5	73.1	72.8	72.6	72.6	72.6	72.6	72.6
500	69.9	69.9	69.9	69.9	69.9	70.7	72.3	73.8	75.4	76.9	76.3	75.8	75.2	74.6	74.3	74.3	74.3	74.3	74.3
630	73.6	73.6	73.6	73.6	73.6	74.0	74.7	75.4	76.1	76.8	76.0	75.2	74.4	73.5	73.1	73.1	73.1	73.1	73.1
800	74.5	74.5	74.5	74.5	74.5	74.5	74.4	74.4	74.3	74.2	73.5	72.8	72.2	71.5	71.1	71.1	71.1	71.1	71.1
1000	75.5	75.5	75.5	75.5	75.5	75.3	74.8	74.2	73.7	73.2	72.8	72.3	71.8	71.4	71.1	71.1	71.1	71.1	71.1
1250	79.7	79.7	79.7	79.7	79.7	79.5	79.1	78.7	78.2	77.8	76.6	75.4	74.2	72.9	72.3	72.3	72.3	72.3	72.3
1600	79.7	79.7	79.7	79.7	79.7	79.6	79.3	79.0	78.7	78.4	77.4	76.4	75.4	74.3	73.8	73.8	73.8	73.8	73.8
2000	81.3	81.3	81.3	81.3	81.3	81.0	80.3	79.6	78.9	78.2	76.4	74.6	72.8	70.9	70.0	70.0	70.0	70.0	70.0
2500	76.1	76.1	76.1	76.1	76.1	76.4	76.9	77.4	77.9	78.4	76.8	75.2	73.6	72.0	71.2	71.2	71.2	71.2	71.2
3150	76.2	76.2	76.2	76.2	76.2	76.1	75.9	75.6	75.4	75.1	73.8	72.5	71.2	69.9	69.2	69.2	69.2	69.2	69.2
4000	78.0	78.0	78.0	78.0	78.0	78.0	78.1	78.1	78.1	78.1	76.6	75.1	73.6	72.1	71.3	71.3	71.3	71.3	71.3
5000	80.1	80.1	80.1	80.1	80.1	80.1	79.9	79.8	79.7	79.5	77.1	74.7	72.3	69.8	68.6	68.6	68.6	68.6	68.6
6300	70.7	70.7	70.7	70.7	70.7	71.1	71.9	72.7	73.4	74.2	72.3	70.3	68.4	66.4	65.4	65.4	65.4	65.4	65.4
8000	64.0	64.0	64.0	64.0	64.0	64.8	66.4	67.9	69.5	71.0	69.0	67.0	65.0	63.0	62.0	62.0	62.0	62.0	62.0
10000	55.9	55.9	55.9	55.9	55.9	57.1	59.4	61.6	63.9	66.2	63.8	61.5	59.1	56.7	55.5	55.5	55.5	55.5	55.5
12500	42.9	42.9	42.9	42.9	42.9	44.5	47.8	51.0	54.2	57.4	55.1	52.8	50.4	48.1	46.9	46.9	46.9	46.9	46.9

Table 7 Heavy Air Carrier (Boeing 767) Detailed Source Levels at 200 feet

1/3 Ocatave Band (Hz)	Sound Pressure Level by Angle from Front of Aircraft (dB)																		
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
12.5	53.4	53.4	53.4	53.4	53.4	54.3	56.1	57.8	59.6	61.3	62.2	63.1	64.0	64.9	65.3	65.3	65.3	65.3	65.3
16	57.8	57.8	57.8	57.8	57.8	58.6	60.1	61.7	63.2	64.7	64.8	64.8	64.9	64.9	64.9	64.9	64.9	64.9	64.9
20	59.0	59.0	59.0	59.0	59.0	59.2	59.5	59.9	60.2	60.5	61.8	63.1	64.4	65.7	66.3	66.3	66.3	66.3	66.3
25	59.8	59.8	59.8	59.8	59.8	60.3	61.2	62.2	63.1	64.0	65.3	66.6	67.8	69.1	69.7	69.7	69.7	69.7	69.7
31	62.6	62.6	62.6	62.6	62.6	63.5	65.1	66.7	68.4	70.0	69.9	69.8	69.8	69.7	69.6	69.6	69.6	69.6	69.6
40	67.5	67.5	67.5	67.5	67.5	67.9	68.5	69.2	69.9	70.5	70.5	70.4	70.4	70.4	70.3	70.3	70.3	70.3	70.3
50	69.3	69.3	69.3	69.3	69.3	69.8	70.7	71.7	72.6	73.5	74.4	75.3	76.2	77.1	77.5	77.5	77.5	77.5	77.5
63	72.0	72.0	72.0	72.0	72.0	72.2	72.7	73.1	73.5	73.9	75.4	76.9	78.3	79.8	80.5	80.5	80.5	80.5	80.5
80	76.4	76.4	76.4	76.4	76.4	76.9	77.8	78.8	79.7	80.6	80.1	79.6	79.0	78.5	78.2	78.2	78.2	78.2	78.2
100	65.3	65.3	65.3	65.3	65.3	65.7	66.3	67.0	67.7	68.3	68.5	68.6	68.7	68.9	68.9	68.9	68.9	68.9	68.9
125	62.0	62.0	62.0	62.0	62.0	62.5	63.5	64.4	65.4	66.3	67.1	68.0	68.8	69.6	70.0	70.0	70.0	70.0	70.0
160	64.6	64.6	64.6	64.6	64.6	65.0	65.6	66.2	66.9	67.5	67.9	68.2	68.6	69.0	69.1	69.1	69.1	69.1	69.1
200	63.5	63.5	63.5	63.5	63.5	64.1	65.2	66.3	67.4	68.5	68.9	69.4	69.8	70.2	70.4	70.4	70.4	70.4	70.4
250	61.4	61.4	61.4	61.4	61.4	62.1	63.4	64.7	66.0	67.3	68.2	69.0	69.9	70.7	71.1	71.1	71.1	71.1	71.1
315	61.5	61.5	61.5	61.5	61.5	62.4	64.2	65.9	67.7	69.4	69.2	69.0	68.8	68.6	68.5	68.5	68.5	68.5	68.5
400	64.2	64.2	64.2	64.2	64.2	65.1	66.9	68.6	70.4	72.1	71.8	71.5	71.1	70.8	70.6	70.6	70.6	70.6	70.6
500	67.9	67.9	67.9	67.9	67.9	68.7	70.3	71.8	73.4	74.9	74.3	73.8	73.2	72.6	72.3	72.3	72.3	72.3	72.3
630	71.6	71.6	71.6	71.6	71.6	72.0	72.7	73.4	74.1	74.8	74.0	73.2	72.4	71.5	71.1	71.1	71.1	71.1	71.1
800	72.5	72.5	72.5	72.5	72.5	72.5	72.4	72.4	72.3	72.2	71.5	70.8	70.2	69.5	69.1	69.1	69.1	69.1	69.1
1000	73.5	73.5	73.5	73.5	73.5	73.3	72.8	72.2	71.7	71.2	70.8	70.3	69.8	69.4	69.1	69.1	69.1	69.1	69.1
1250	77.7	77.7	77.7	77.7	77.7	77.5	77.1	76.7	76.2	75.8	74.6	73.4	72.2	70.9	70.3	70.3	70.3	70.3	70.3
1600	77.7	77.7	77.7	77.7	77.7	77.6	77.3	77.0	76.7	76.4	75.4	74.4	73.4	72.3	71.8	71.8	71.8	71.8	71.8
2000	79.3	79.3	79.3	79.3	79.3	79.0	78.3	77.6	76.9	76.2	74.4	72.6	70.8	68.9	68.0	68.0	68.0	68.0	68.0
2500	74.1	74.1	74.1	74.1	74.1	74.4	74.9	75.4	75.9	76.4	74.8	73.2	71.6	70.0	69.2	69.2	69.2	69.2	69.2
3150	74.2	74.2	74.2	74.2	74.2	74.1	73.9	73.6	73.4	73.1	71.8	70.5	69.2	67.9	67.2	67.2	67.2	67.2	67.2
4000	76.0	76.0	76.0	76.0	76.0	76.0	76.1	76.1	76.1	76.1	74.6	73.1	71.6	70.1	69.3	69.3	69.3	69.3	69.3
5000	78.1	78.1	78.1	78.1	78.1	78.1	77.9	77.8	77.7	77.5	75.1	72.7	70.3	67.8	66.6	66.6	66.6	66.6	66.6
6300	68.7	68.7	68.7	68.7	68.7	69.1	69.9	70.7	71.4	72.2	70.3	68.3	66.4	64.4	63.4	63.4	63.4	63.4	63.4
8000	62.0	62.0	62.0	62.0	62.0	62.8	64.4	65.9	67.5	69.0	67.0	65.0	63.0	61.0	60.0	60.0	60.0	60.0	60.0
10000	53.9	53.9	53.9	53.9	53.9	55.1	57.4	59.6	61.9	64.2	61.8	59.5	57.1	54.7	53.5	53.5	53.5	53.5	53.5
12500	40.9	40.9	40.9	40.9	40.9	42.5	45.8	49.0	52.2	55.4	53.1	50.8	48.4	46.1	44.9	44.9	44.9	44.9	44.9

Table 8 Large Air Carrier (Boeing 737-300) Detailed Source Levels at 200 feet

1/3 Ocatave Band (Hz)	Sound Pressure Level by Angle from Front of Aircraft (dB)																		
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
50	69.3	69.3	69.3	64.0	66.7	68.3	68.7	69.0	69.5	70.1	71.3	72.2	72.9	73.6	73.9	73.8	73.0	73.0	73.0
63	70.2	70.2	70.2	73.8	72.3	71.3	70.8	71.8	72.3	72.4	73.1	76.1	81.4	78.7	76.8	75.9	74.0	74.0	74.0
80	73.6	73.6	73.6	78.6	76.4	74.8	73.9	74.6	75.3	75.9	77.2	78.9	81.0	79.6	79.4	80.4	76.2	76.2	76.2
100	74.7	74.7	74.7	77.3	72.9	71.7	73.8	75.1	76.2	77.1	78.0	79.6	81.9	80.6	80.5	81.5	79.9	79.9	79.9
125	75.5	75.5	75.5	75.1	76.3	76.3	75.1	75.3	75.6	76.0	78.8	80.9	82.3	81.5	80.6	79.7	80.8	80.8	80.8
160	73.4	73.4	73.4	77.6	79.3	78.9	76.5	76.4	76.0	75.5	80.0	80.7	77.6	80.3	81.4	80.9	77.9	77.9	77.9
200	72.4	72.4	72.4	76.3	74.5	73.6	73.7	73.6	74.2	75.5	76.4	77.6	78.9	79.4	79.7	79.8	75.6	75.6	75.6
250	74.9	74.9	74.9	78.3	76.4	75.8	76.5	75.9	75.8	76.2	76.7	78.3	81.0	82.9	82.5	79.8	78.2	78.2	78.2
315	76.6	76.6	76.6	80.2	78.6	78.0	78.3	77.5	78.0	79.9	80.4	81.4	82.9	84.0	83.9	82.4	80.8	80.8	80.8
400	75.6	75.6	75.6	80.1	79.0	78.0	76.9	77.2	77.5	77.9	78.4	79.7	81.9	81.6	79.9	77.0	78.0	78.0	78.0
500	75.2	75.2	75.2	79.1	78.6	77.7	76.2	76.0	76.1	76.4	77.5	78.5	79.3	79.5	78.7	77.0	76.4	76.4	76.4
630	76.9	76.9	76.9	81.5	79.1	77.3	76.1	76.0	76.3	77.0	78.5	80.0	81.5	82.2	80.9	77.8	75.1	75.1	75.1
800	76.9	76.9	76.9	80.6	77.8	75.7	74.3	73.9	74.5	76.0	77.5	79.6	82.3	81.9	80.0	76.6	73.8	73.8	73.8
1000	78.9	78.9	78.9	79.3	75.2	72.5	71.2	71.1	71.5	72.4	73.9	77.4	82.8	80.0	77.3	74.7	72.2	72.2	72.2
1250	77.5	77.5	77.5	76.6	73.4	71.4	70.6	70.5	70.3	70.0	71.6	75.4	81.4	78.1	75.3	73.1	70.9	70.9	70.9
1600	77.1	77.1	77.1	77.4	73.9	71.3	69.7	69.9	69.6	68.9	70.7	74.2	79.3	77.3	74.9	72.2	70.0	70.0	70.0
2000	61.0	61.0	61.0	81.0	76.9	73.6	71.1	70.9	70.4	69.6	71.9	75.0	78.7	77.0	74.8	72.2	69.8	69.8	69.8
2500	64.9	64.9	64.9	85.9	80.7	76.6	73.5	72.1	71.1	70.6	73.5	76.6	79.9	77.5	74.9	72.2	69.7	69.7	69.7
3150	83.6	83.6	83.6	85.0	81.1	77.2	73.4	71.0	70.1	70.6	73.7	76.4	78.9	77.8	75.4	71.9	69.7	69.7	69.7
4000	79.6	79.6	79.6	81.3	79.0	76.2	72.9	70.6	69.4	69.2	71.7	74.4	77.3	75.8	74.3	72.7	69.8	69.8	69.8
5000	78.9	78.9	78.9	79.9	79.4	77.2	73.3	71.0	68.9	67.0	72.0	76.0	79.1	77.1	75.4	74.0	67.0	67.0	67.0
6300	76.5	76.5	76.5	78.5	78.5	75.9	70.6	68.4	67.5	67.9	70.9	74.4	78.5	76.5	74.5	72.5	67.8	67.8	67.8
8000	74.3	74.3	74.3	76.2	77.7	75.1	68.6	68.5	68.6	68.8	72.3	76.1	80.1	79.5	77.3	73.6	70.7	70.7	70.7
10000	75.7	75.7	75.7	78.8	78.2	77.4	76.4	77.3	72.2	60.9	77.1	87.2	91.2	88.5	84.9	80.2	76.8	76.8	76.8

Table 9 Regional and Corporate Jet (Canadair Regional Jet) Detailed Source Levels at 200 feet

1/3 Ocatave Band (Hz)	Sound Pressure Level by Angle from Front of Aircraft (dB)																		
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
12.5	59.5	59.4	59.2	58.9	58.6	59.3	61.1	62.2	61.3	60.5	61.0	61.6	61.2	60.5	60.1	60.0	62.1	70.8	79.6
16	63.0	62.1	61.1	60.6	60.3	60.7	61.8	62.5	61.9	61.2	62.1	63.1	62.4	61.2	60.9	61.4	63.4	69.9	76.4
20	63.9	62.3	60.6	60.1	60.0	60.5	61.5	62.5	63.5	64.5	64.1	63.8	62.8	61.5	61.0	61.2	62.6	67.5	72.4
25	65.4	66.1	66.7	65.2	62.9	62.0	62.3	62.9	64.7	66.5	65.3	64.1	63.9	64.0	63.9	63.7	64.5	68.0	71.6
31	66.5	67.0	67.5	66.7	65.5	64.9	64.9	65.1	65.7	66.3	67.4	68.4	67.3	65.4	64.6	65.1	66.2	69.4	72.6
40	69.6	68.4	67.1	66.7	66.5	67.0	68.1	69.0	69.1	69.2	69.6	70.1	69.2	67.9	67.2	67.0	67.5	70.4	73.3
50	71.4	70.7	70.0	68.9	67.8	67.1	67.0	67.3	69.0	70.6	70.4	70.2	69.8	69.3	69.1	69.2	69.8	71.7	73.7
63	72.7	71.8	70.9	70.1	69.4	69.0	68.9	69.3	71.0	72.6	72.0	71.4	71.1	70.8	70.9	71.5	72.1	72.7	73.3
80	72.7	72.6	72.5	72.1	71.6	71.9	73.0	74.2	75.2	76.2	75.7	75.1	74.4	73.7	73.5	73.8	74.0	73.7	73.3
100	72.3	73.4	74.5	75.7	76.9	77.6	77.7	77.7	77.4	77.0	77.5	78.1	77.8	77.3	76.9	76.5	75.8	74.1	72.4
125	73.6	75.4	77.2	78.1	78.6	78.6	77.9	77.4	77.2	77.0	77.3	77.5	77.5	77.3	76.4	74.9	73.4	72.0	70.7
160	73.1	75.1	77.1	77.5	77.4	76.9	76.0	75.4	75.9	76.3	76.3	76.3	75.1	73.5	72.3	71.5	70.8	70.4	70.0
200	72.0	73.5	74.9	74.5	73.4	73.3	74.2	74.9	75.0	75.0	75.8	76.7	75.1	72.6	71.7	72.4	72.4	70.3	68.2
250	70.7	71.0	71.3	71.8	72.3	72.6	72.6	72.8	73.8	74.7	74.6	74.5	73.2	71.5	71.3	72.5	73.0	71.2	69.5
315	74.9	76.1	77.3	77.0	76.1	76.4	77.7	78.9	79.8	80.6	80.2	79.7	79.1	78.4	77.9	77.6	76.6	73.9	71.2
400	72.6	75.3	77.9	77.0	74.9	74.6	76.3	77.5	77.3	77.2	77.3	77.5	76.8	75.9	75.6	75.8	75.4	73.5	71.6
500	70.3	71.1	72.0	71.0	69.4	69.6	71.5	72.7	72.1	71.4	71.5	71.7	70.5	68.8	68.5	69.5	69.9	68.8	67.7
630	66.9	67.9	68.9	69.6	70.1	71.2	72.7	73.7	73.1	72.5	71.2	69.9	69.9	70.3	70.6	70.9	70.8	69.4	68.1
800	69.2	69.2	69.3	69.7	70.3	71.4	73.1	74.2	73.3	72.5	71.0	69.6	68.9	68.4	69.1	70.9	71.7	69.5	67.2
1000	72.8	73.0	73.2	71.6	69.5	67.7	66.3	65.5	66.4	67.3	66.5	65.8	65.3	64.9	65.7	67.6	68.7	67.3	65.9
1250	74.7	76.2	77.7	76.1	73.4	70.8	68.5	66.5	65.7	64.9	64.9	65.0	66.1	67.6	68.4	68.3	67.9	66.5	65.1
1600	77.1	79.0	80.9	80.0	78.2	76.0	73.3	70.8	68.6	66.4	67.1	67.7	68.9	70.2	70.5	69.9	68.9	66.7	64.5
2000	74.3	76.4	78.5	77.8	76.3	74.4	72.1	70.0	68.4	66.8	67.6	68.5	69.4	70.4	70.9	70.9	70.2	67.3	64.5
2500	76.5	74.6	72.8	71.3	69.9	68.4	66.8	65.8	66.4	67.0	66.0	65.0	64.4	64.1	64.5	65.8	66.3	64.1	62.0
3150	74.0	73.9	73.8	73.4	72.9	71.3	68.6	66.5	66.2	65.9	65.1	64.3	64.6	65.2	65.4	65.3	64.8	63.0	61.2
4000	74.3	74.1	73.9	74.1	74.5	73.5	71.0	68.8	67.0	65.3	65.7	66.1	66.8	67.6	67.5	66.5	65.1	62.5	59.9
5000	75.7	76.7	77.7	77.7	77.4	75.5	72.0	69.0	67.8	66.6	67.5	68.4	69.0	69.5	69.5	68.9	67.6	64.5	61.4
6300	73.9	74.2	74.4	73.9	73.0	71.8	70.3	68.6	66.8	65.0	66.5	67.9	68.9	69.7	69.5	68.3	66.6	63.2	59.9
8000	70.7	69.5	68.4	68.4	68.8	67.7	65.1	63.0	62.1	61.3	62.5	63.6	65.0	66.5	66.4	64.6	62.3	58.8	55.2
10000	66.1	65.4	64.8	64.7	64.9	63.9	61.7	60.0	59.5	59.1	60.2	61.3	62.6	63.9	63.4	61.2	58.7	55.2	51.6
12500	60.5	59.9	59.3	59.4	59.6	58.6	56.3	54.5	53.9	53.4	54.8	56.2	57.0	57.7	56.9	54.5	51.7	47.6	43.5
16000	56.7	56.0	55.4	55.1	54.9	53.4	50.7	48.4	47.1	45.9	47.5	49.1	50.5	51.8	51.2	48.7	45.9	41.9	37.9
20000	48.1	47.6	47.1	47.2	47.4	46.3	43.8	41.7	40.5	39.3	41.7	44.2	45.3	46.0	44.8	41.7	38.3	34.4	30.4

Table 10 Propeller Aircraft (Beech 1900) Detailed Source Levels at 200 feet

1/3 Ocatave Band (Hz)	Sound Pressure Level by Angle from Front of Aircraft (dB)																		
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
10	86.4	87.2	87.9	85.0	84.1	78.7	75.7	76.0	70.5	77.5	67.8	70.1	72.9	73.8	80.9	77.1	83.4	78.4	73.4
12.5	86.8	87.6	88.3	85.4	84.5	79.1	76.1	76.4	70.9	77.9	68.2	70.5	73.3	74.2	81.3	77.6	83.8	78.8	73.8
16	87.4	88.6	89.9	84.6	83.2	77.2	74.4	74.6	69.4	75.1	67.1	69.2	71.4	72.6	79.7	75.5	82.3	77.3	72.3
20	87.2	88.2	90.0	83.7	82.4	76.4	73.5	74.0	68.9	73.9	66.6	68.9	70.6	72.0	78.9	74.8	81.6	76.6	71.6
25	85.5	85.5	88.4	80.8	80.4	75.2	72.2	73.2	68.1	72.7	65.5	68.6	70.0	71.0	77.5	74.1	80.2	75.2	70.2
31	83.5	83.6	86.4	78.0	80.0	74.4	71.5	72.7	68.5	72.4	66.9	68.6	70.6	71.3	77.1	73.9	79.1	74.1	69.1
40	81.2	82.0	84.8	76.4	79.3	74.3	71.2	72.4	70.3	72.5	69.8	70.4	71.3	74.1	76.7	73.6	78.2	73.2	68.2
50	78.4	80.4	84.7	75.1	76.3	73.5	71.5	72.0	70.7	73.3	71.6	72.5	71.8	72.8	76.3	73.3	77.8	72.8	67.8
63	77.2	79.1	83.6	76.7	78.9	78.1	76.1	75.3	75.0	77.2	75.3	75.9	76.0	76.3	78.8	74.5	77.7	72.7	67.7
80	82.2	82.0	83.7	78.5	81.3	79.3	77.9	77.2	76.5	80.8	79.3	79.2	79.8	80.4	79.4	78.2	79.4	74.4	69.4
100	76.4	77.4	78.9	73.8	75.2	72.1	71.9	71.2	70.2	71.1	70.7	71.7	73.1	72.6	75.4	73.0	76.1	71.1	66.1
125	79.4	80.6	81.7	77.7	78.1	76.8	74.3	73.4	72.4	72.2	71.8	72.8	74.3	76.2	76.2	73.8	75.1	70.1	65.1
160	87.7	86.4	85.4	82.7	81.7	79.4	75.7	73.9	74.3	75.3	76.1	76.0	75.2	76.9	80.9	78.7	74.3	69.3	64.3
200	82.9	83.6	84.3	79.9	75.6	73.8	72.2	71.2	71.3	71.2	71.1	72.7	74.4	74.8	76.4	76.3	72.0	67.0	62.0
250	86.2	85.8	85.7	88.3	77.6	73.6	72.7	69.9	69.7	69.2	69.6	71.6	74.1	73.9	78.8	77.4	69.1	64.1	59.1
315	85.1	85.4	86.6	87.5	77.0	73.3	72.7	72.4	73.1	71.2	72.4	72.7	74.8	75.7	76.4	76.0	67.7	62.7	57.7
400	84.2	83.6	84.0	82.0	75.3	70.5	70.7	69.0	68.2	68.7	68.1	68.8	70.6	70.2	73.2	74.7	63.9	58.9	53.9
500	84.3	83.5	82.4	83.0	75.5	70.8	70.5	69.5	69.3	69.0	69.9	69.1	69.5	69.5	73.8	73.0	61.6	56.6	51.6
630	80.3	80.1	79.9	79.2	72.8	71.1	69.9	69.5	70.1	69.5	70.5	70.9	68.6	69.1	72.3	70.5	60.5	55.5	50.5
800	77.1	77.9	76.3	76.5	72.4	70.4	68.9	68.6	69.8	69.3	68.8	69.3	68.5	67.6	69.8	66.8	56.4	51.4	46.4
1000	74.9	75.4	73.8	75.0	70.7	68.6	68.2	66.6	66.9	66.3	66.9	68.3	67.0	66.6	68.2	64.2	54.0	49.0	44.0
1250	71.5	73.3	72.0	71.9	68.8	67.0	67.2	64.7	64.3	63.4	65.4	65.9	65.3	64.3	66.4	63.0	52.5	47.5	42.5
1600	70.3	71.4	70.5	69.7	67.7	66.3	67.6	65.4	64.6	64.1	66.1	65.2	65.2	63.9	64.4	61.4	50.1	45.1	40.1
2000	67.6	69.4	69.8	67.6	66.5	69.2	71.8	65.9	67.8	68.3	69.4	64.7	65.7	62.6	64.0	59.5	47.5	42.5	37.5
2500	68.9	70.4	69.0	67.4	65.6	65.9	67.2	65.3	62.0	62.1	59.5	58.5	60.0	59.0	59.5	57.1	44.8	39.8	34.8
3150	71.0	71.1	70.1	68.5	66.8	67.3	69.4	67.1	63.4	62.5	61.3	58.4	61.7	60.5	60.8	57.7	46.6	41.6	36.6
4000	69.6	70.1	69.6	66.4	64.7	65.1	66.4	65.1	61.2	60.6	62.9	60.7	62.0	60.6	60.4	56.5	43.8	38.8	33.8
5000	71.0	71.3	70.6	68.7	66.0	65.8	66.1	65.2	62.0	61.5	59.8	59.1	60.0	57.6	56.1	53.9	40.1	35.1	30.1
6300	70.5	71.1	70.1	68.0	66.0	64.8	65.0	63.4	60.8	60.0	58.0	56.4	59.0	56.7	55.6	52.8	39.9	34.9	29.9
8000	68.7	70.4	69.2	66.9	64.6	64.0	64.0	62.3	59.8	59.4	57.8	56.9	58.2	55.4	55.2	52.0	39.2	34.2	29.2
10000	65.7	67.2	66.1	63.9	61.7	60.7	60.9	58.9	56.4	56.2	53.7	52.4	54.5	52.5	52.1	49.2	38.3	33.3	28.3

B.2 Directivity Plots

The following five figures present directivity plots of the A-weighted noise emission levels of each of the aircraft groups used in the modeling. The numerical values represented in the graphs are given in Table 2 - Taxi Source A-weighted Emission Levels.

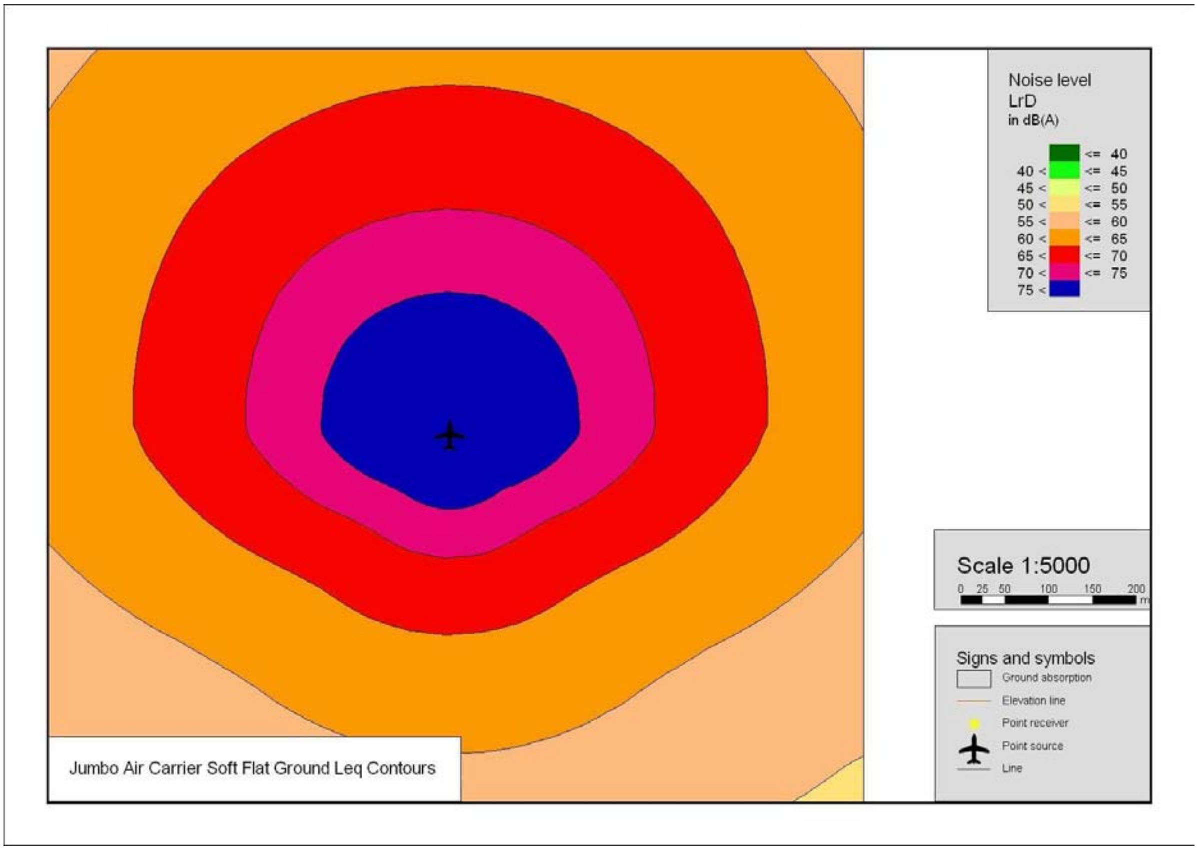

Figure 10 Jumbo Air Carrier (Boeing 747) A-weighted Taxi Noise Emission Directivity

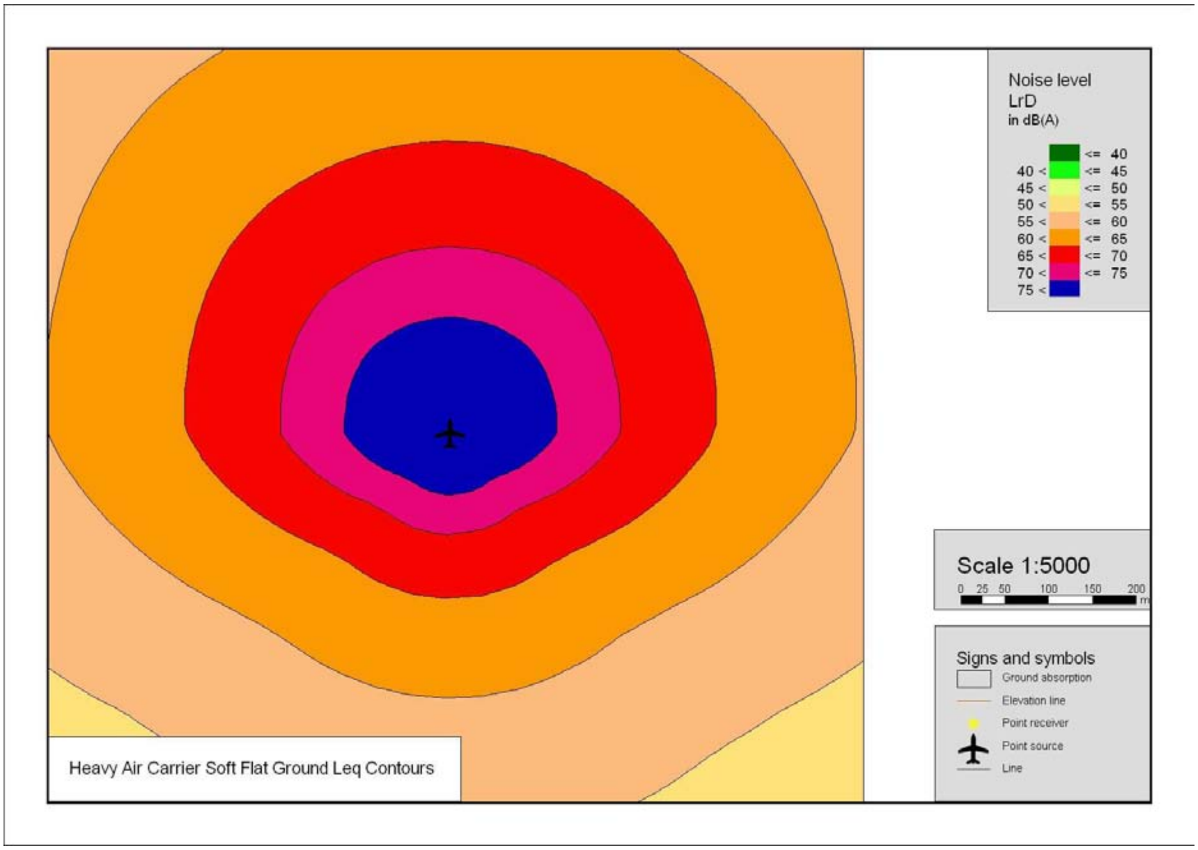

Figure 11 Heavy Air Carrier (Boeing 767) A-weighted Taxi Noise Emission Directivity

Figure 12 Large Air Carrier (Boeing 737-300) A-weighted Taxi Noise Emission Directivity

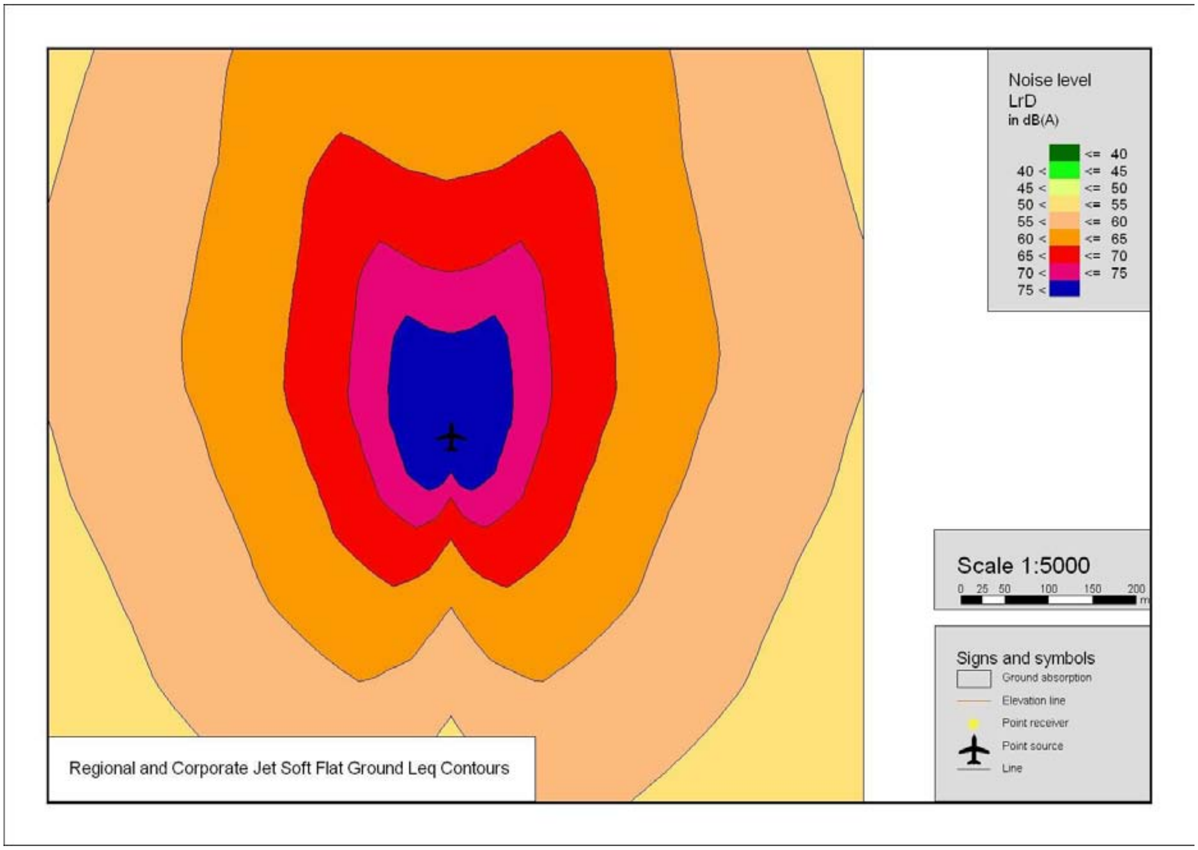

Figure 13 Regional and Corporate Jet (Canadair Regional Jet) A-weighted Taxi Noise Emission Directivity

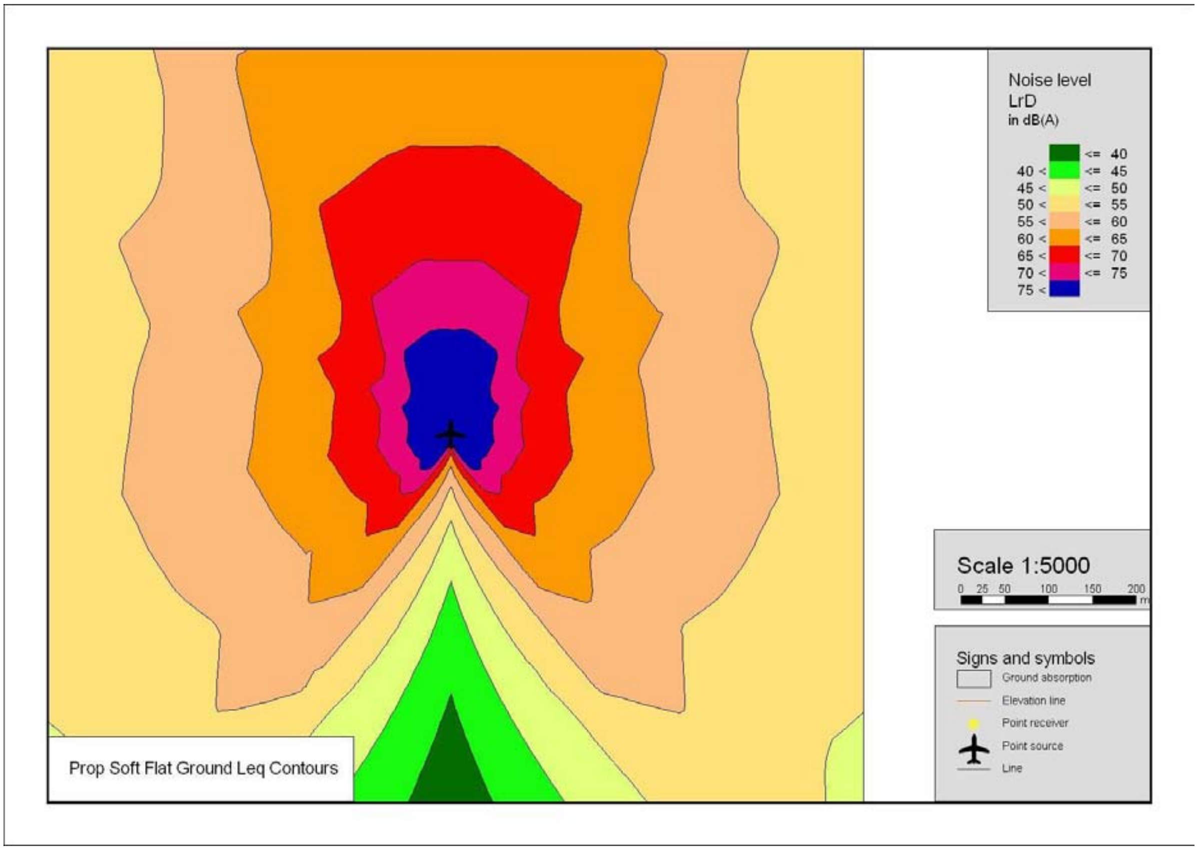

Figure 14 Propeller Aircraft (Beech 1900) A-weighted Taxi Noise Emission Directivity

APPENDIX C COMPUTED PARTIAL DNL VALUES BY LOCATION

Figure 15 and Figure 16 display the DNL results graphically for all three scenarios broken down by taxi/queue location for Receivers 10 and 12, respectively. The total DNL is also displayed at the right of each graph. Both graphs show small decreases in noise level contributions from locations N_5 through N_9 for the Limit All Jets condition. However, the contributions to DNL from these locations are overshadowed by locations N_1 through N_4 in the contribution to total DNL.

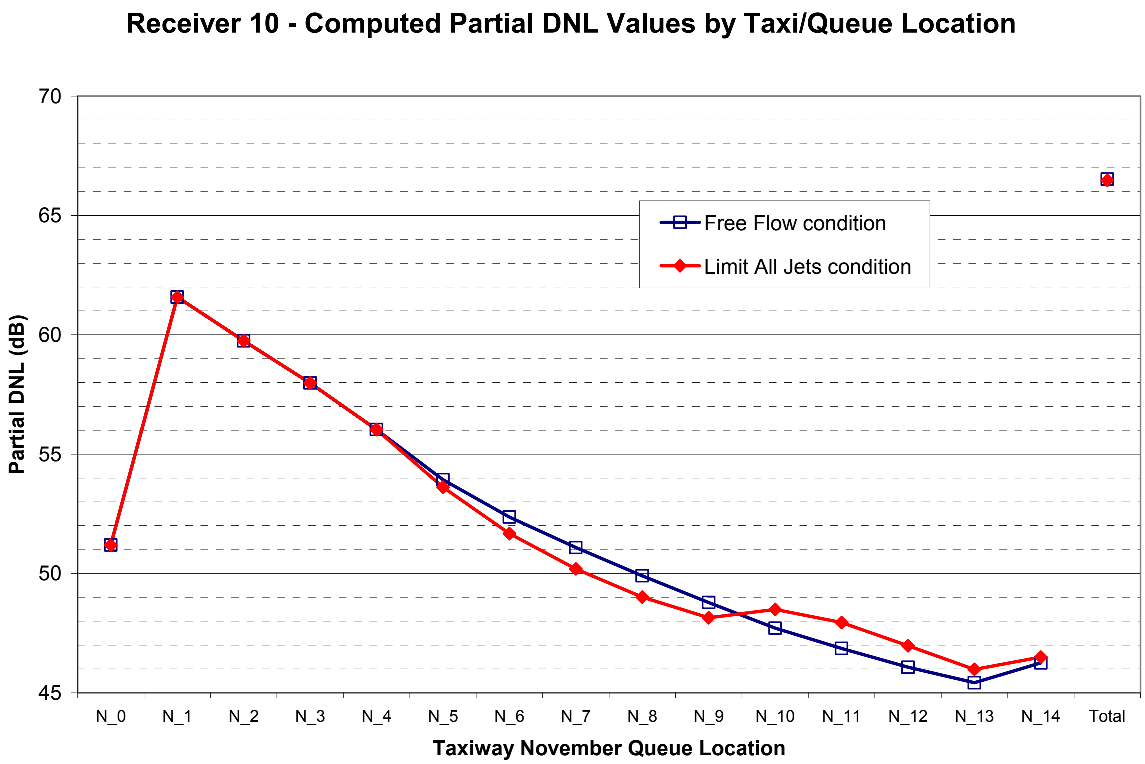

Figure 15 Receiver 10 Computed DNL Values by Taxi/Queue Location

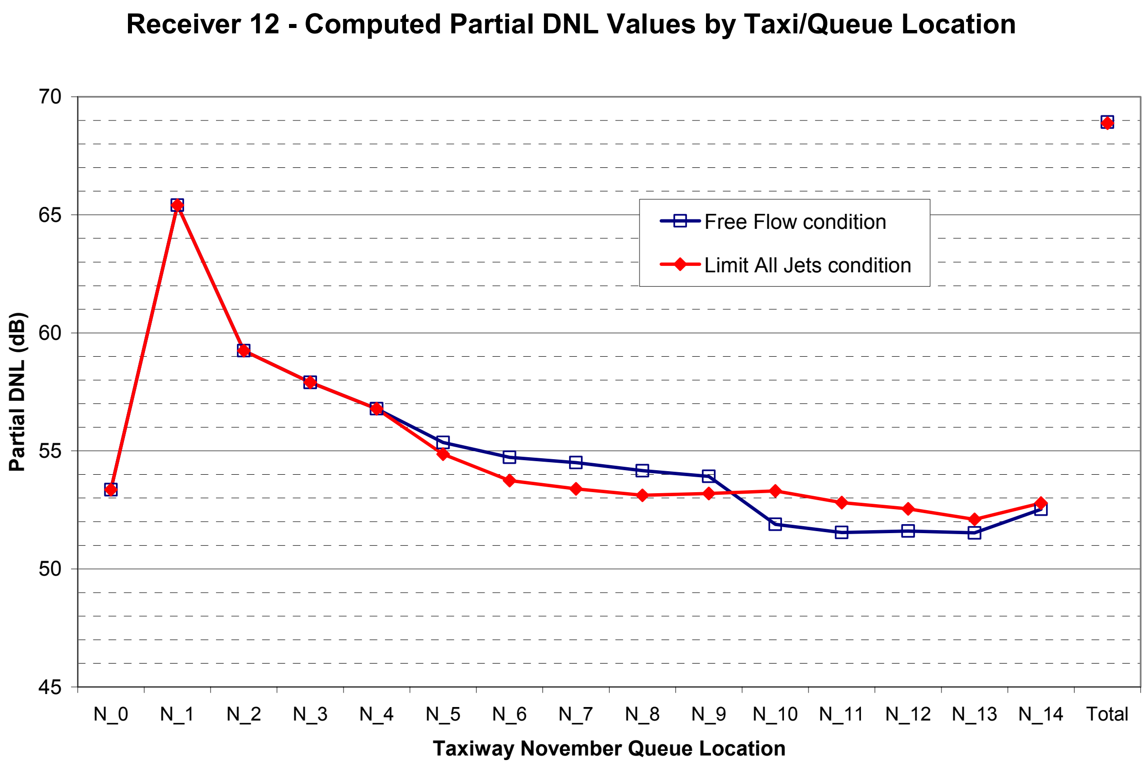

Figure 16 Receiver 12 Computed DNL Values by Taxi/Queue Location